DEPARTMENT OF TECHNOLOGY

AERONAUTICAL ENGINEERING REVIEW

JANUARY 1953

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The Aircraft: Lockheed F-94
The Engine: Pratt & Whitney Aircraft J-48 Jet
Fuel Metering: Holley Turbine Control

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AERONAUTICAL ENGINEERING REVIEW

Cover—This shot of Lockheed Aircraft Corporation's F-94C Starfire, taken recently over the California desert, shows the Starfire a split second after a group of 2.75-in. air-to-air rockets has been fired from its nose. Smoke from the released rockets is shown as it swirls around the ship; however, within a few moments after this picture was taken, and in accordance with the usual practice, the interceptor pulled up out of the smoke and into the clear. The F-94C carries 24 rockets in its nose and can carry more in wing pods.

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I. A. S. News

A Record of People and Events of Interest to Institute Members

Fourth International Aeronautical Conference Set for September

Conference Set for September 15–17 in London, England; Twelve Papers to Be Presented during Technical Sessions; S.B.A.C. Show Scheduled for Preceding Week; Visits to Industrial and Governmental Installations Being Arranged

THE FOURTH INTERNATIONAL AERONAUTICAL CONFERENCE will be held in London, England, on September 15, 16, and 17. The scheduling of the Conference at this time will make this coming September one of the busiest in the annals of aeronautical history and will give the delegates to the Conference 2 full weeks in which to view firsthand the latest developments in British aviation.

Immediately preceding the Fourth International Aeronautical Conference are two outstanding events in British aviation. One is the Society of British Aircraft Constructors' Coronation Year Flying Display and Exhibition at Farnborough. The other is the Wilbur Wright Lecture, which is presented annually by the Royal Aeronautical Society.

▶ **Two-Week Schedule**—The following is the schedule for the 2-week period (September 7–18) as it takes form at the time the AERONAUTICAL ENGINEERING REVIEW goes to press:

September 7–13:	S.B.A.C. show at Farnborough.
September 10–11:	Visits to local facilities.
September 14:	Wilbur Wright Lecture and Reception.
September 15–17:	Fourth International Aeronautical Conference.
September 18:	Visits to local facilities.

In view of the foregoing, it is suggested that delegates to the Conference plan their time so that they can remain in London from Monday, September 7, through Saturday, September 19.

▶ **Tentative Conference Schedule**—The technical sessions will probably be held at University College in London, where ample room for lectures and discussions would be available.

Whereas at the Third International Aeronautical Conference 20 technical papers were presented, it was decided to limit the total number of papers to be delivered during the course of the forthcoming Conference to twelve. This will mean that six of the papers will be presented by the British, while the Americans will give the other six.

▶ **Clearances**—U.S. delegates must be able to show documentary evidence of security clearance (at least through "Confidential") by the Air Force, Navy, or other qualified Government agency. It is expected that certain of the material presented during the Conference, as well as some of the plant visits, will involve classified information.

The usual passport and visas are also necessary.

▶ **Why England, Not U.S.A.**—As the members of the Institute will recall, I.A.S. President Wellwood E. Beall announced at last summer's Annual Summer Meeting Dinner that the Fourth International Aeronautical Conference would be held in Los Angeles.

For the benefit of I.A.S. members who may not be cognizant of the reasons for changing the meeting place, the following excerpt from the Editorial in the November, 1952, REVIEW is quoted:

"Immediately following the announcement it became obvious that the close proximity of the date to the regular Aeronautics Meeting of the S.A.E. would create an undesirable situation with respect to both meetings. After consultation with the Management of the S.A.E., it was agreed that any such conflict should be avoided, and we advised the R.Ae.S. that a meeting at that time in the United States could not be arranged. Several alternatives were proposed."

On September 25, the R.Ae.S. Council met, and it was decided to hold the Conference again in England in conjunction with the 1953 S.B.A.C. show. An official invitation was extended to the I.A.S., which was unanimously accepted by the Executive Committee of the I.A.S. Council at the October 30 meeting.

▶ **Program Committee**—Six Americans have been selected to serve on the Program Committee for the Fourth International Aeronautical Conference. They will be responsible for the American contributions to this forthcoming meeting. Charles J. McCarthy, Vice-President of United Aircraft Corporation, will serve as Chairman of the Program Committee. The other committee members are: Theodore P. Wright, Vice-President—Research, Cornell University; Hugh L. Dryden, Director, N.A.C.A.; Preston R. Bassett, President, Sperry Gyroscope Company, Division of The Sperry Corporation; Rear Adm. Lawrence B. Richardson, U.S.N. (Ret.), Senior Vice-President, General Dynamics Corporation; and Jerome C. Hunsaker, Professor of Aeronautical Engineering, Massachusetts Institute of Technology.

General Hoyt S. Vandenberg to Speak at Honors Night Dinner

The Honors Night Dinner of the Institute of the Aeronautical Sciences, to be held Monday, January 26, in the Grand Ballroom of New York's Hotel Astor, will have as its guest of honor and principal speaker Gen. Hoyt S. Vandenberg, U.S.A.F., Chief of Staff of the U.S. Air Force.

Wellwood E. Beall, I.A.S. President for 1952, who, at the Dinner, will relinquish his office to the incoming President, Chares J. McCarthy, will introduce General Vandenberg.

▸ **The Speaker**—General Vandenberg, who was born in Milwaukee, Wis., on January 24, 1899, was graduated from the United States Military Academy on June 12, 1923, and was commissioned a Second Lieutenant in the Air Service.

In the fall of that year, he entered the Air Service Flying School at Brooks A.F.B., Tex., from which he was graduated the following February. He then took the advanced course at the Air Service Advanced Flying School at Kelly A.F.B., Tex., and in September of 1924 received his first Air Force assignment with the Third Attack Group at Kelly A.F.B., with which he transferred to Fort Crockett, Tex., in August, 1926. After 3 years with this group, during which he took over the 90th Attack Squadron as his first command, he became an instructor at the Air Corps Primary Flying School at March A.F.B., Calif.

In May, 1929, General Vandenberg went to Schofield Barracks, Hawaii, to join the Sixth Pursuit Squadron, of which he assumed command the following November. In September of 1931, he began 2 years of service as a Flying Instructor at Randolph A.F.B., Tex., and in March, 1933, became a Flight Commander and Deputy Stage Commander there.

General Vandenberg entered the Air Corps Tactical School, Maxwell A.F.B., Ala., in August, 1934, and was graduated from there the following June. Two months later, he enrolled in the Command and General Staff School at Fort Leavenworth, Kan., and completed that course in June, 1936. He then became an Instructor at the Air Corps Tactical School at Maxwell A.F.B., where he taught until he entered the Army War College in September, 1936.

After graduating from the War College in June, 1939, General Vandenberg was assigned to the Plans Division in the Office of the Chief of the Air Corps. A few months after this nation's formal entry into World War II, he became Operations and Training Officer of the Air Staff. For his services in these two positions, he received the Distinguished Service Medal.

In June, 1942, General Vandenberg was assigned to the United Kingdom and assisted in the organization of the Air Forces in North Africa. While in Great Britian, he was appointed Chief of Staff of the 12th Air Force, which he helped to organize.

In February of 1943, he became Chief of Staff of the Northwest African Strategic Air Force. With this Air Force, he flew on numerous missions over Tunisia, Italy, Sardinia, Sicily, and Pantelleria during the North African campaign. For his services at this time, he was awarded both the Silver Star and the Distinguished Flying Cross. For his organizational ability with the 12th Air Force and his work as Chief of Staff of the Northwest African Strategic Air Force, he was given the Legion of Merit.

General Vandenberg, in August of 1943, was assigned to the Air Force Headquarters as Deputy Chief of Air Staff. A month later, he became Head of an Air Mission to Russia under Ambassador Harriman and returned to the United States in January, 1944. Two months later, he was transferred to the European Theater and in April, 1944, was designated Deputy Air Commander-in-Chief of the Allied Expeditionary Forces and Commander of its American Air Component.

In August of 1944, General Vandenberg assumed command of the Ninth Air Force, and the following November he received an Oak Leaf Cluster to the Distinguished Service Medal for his part in planning the Normandy invasion.

General Vandenberg was appointed Assistant Chief of Air Staff at the Air Force Headquarters in July of 1945. The following January, he became Director of Intelligence on the War Department General Staff, where he served until his appointment in June of 1946 as Director of Central Intelligence. He returned to duty with the Air Force in April, 1947, and on the following June 15 became Deputy Commander and Chief of Air Staff. On October 1, 1947, he was designated Vice Chief of Staff of the U.S. Air Force and was promoted to the rank of General.

On April 30, 1948, Gen. Hoyt S. Vandenberg became Chief of Staff of the U.S. Air Force, succeeding Gen. Carl Spaatz.

▸ **Technical Sessions Program**—The Technical Sessions scheduled for the Twenty-First Annual Meeting will cover a 4-day period, from January 26 to 29.

Simultaneous sessions are planned for January 26. Those on Flight Propulsion and Structures will be held in the morning; sessions on Aircraft Design and Rocket Propulsion will be conducted in the afternoon. The evening will be taken up with the Honors Night Dinner.

On January 27, three sessions on Aerodynamics are planned for the morning, afternoon, and evening.

There will be two simultaneous sessions on the morning of January 28—viz., Electronics in Aviation and Meteorology. The Electronics Session will be on the "Impact of Electronic Trends on Aircraft Design." The afternoon and evening sessions of that day will be given over to an Electronics Symposium on "Electronic Control and Stabilization of Aircraft." The I.A.S. Annual Business Meeting will be held at 5 p.m. on this day.

The fourth and final day of this meeting, January 29, will have two simultaneous sessions in the morning. These will be on Aviation Medicine and Motorless Flight. A session on Air Transport—Safety will be held in the afternoon, and one on Rotating Wing Aircraft will take place during the final evening of the meeting.

Several of the sessions will be given in cooperation with other engineering societies.

I.A.S. News Notes

January 1953

IAS NEWS NOTES — A NEW MONTHLY FEATURE

This little green sheet introduces a new and — what we hope will be — important service to Institute members and Review readers. Its obvious purpose is to give last minute information and news items received too late for inclusion in the printed magazine.

One of its important functions will be to announce National and Section meetings currently scheduled throughout the country. A Meetings Calendar for each current month will always be found on the reverse side of this page.

The brief notes carried in this sheet each month are not intended to supplant any present features of the IAS News Section of the Review. A more complete coverage of all items, announcements, etc., appearing here will be made in following issues of the magazine.

* * * * *

INTERNATIONAL TELEMETERING CONFERENCE PLANNED

A three-day conference, sponsored jointly by the I.A.S., I.R.E., A.I.E.E., and the I.S.A., will be held in Chicago at the Edgewater Beach Hotel, May 20, 21, & 22. The importance and value of this meeting is pointed-up by the fact that representatives of European countries will also attend and present papers.

* * * * *

NECROLOGY

Justin A. Fitz., A.M.I.A.S., Director of Advertising and Public Information, Sperry Gyroscope Co., died suddenly of a heart attack December 9.

Sherman S. Graves, A.M.I.A.S., General Manager, Helicopter Div., Cessna Aircraft Corp., killed in an airplane accident December 15.

* * * * *

ARTICLES SCHEDULED FOR THE FEBRUARY REVIEW

"Reliability in Guided Missile Systems," R. R. Carhart, The Rand Corporation.
"Large Extrusion Press Operations and Production Problems in Aluminum," T. F. McCormick, Aluminum Co. of America.
"Combat-Ready Aircraft," Colonel Bernard A. Schriever, U.S.A.F.
"Laboratory Simulation of Aerodynamic Heating for Transient Temperature Measurements," L. H. Wilson and J. B. Falk, Washington University.
"Eighth International Congress on Theoretical & Applied Mechanics," N.J. Hoff, Polytechnic Institute of Brooklyn.
"Automatic Reduction of Wind-Tunnel Data," V.S.Haneman, L.L.Rausch, R.J.Leitz and U.A.Cotecchia, University of Michigan.

* * * * *

CALENDAR OF I.A.S. NATIONAL MEETINGS

Jan.	26-29	Annual Meeting and Honors Night Dinner, Hotel Astor, New York
Mar.	13	Annual Flight Propulsion Meeting, Carter Hotel, Cleveland, Ohio
July	15-16	Annual Summer Meeting and Honors Dinner, Los Angeles.California
Sept.	7 -17	Fourth International Aeronautical Conference, London, England

* * * * *

I.A.S. News Notes (con't.)

CALENDER OF SECTION MEETINGS

Jan. 6---Seattle Section: University of Washington, 8:00 p.m. Presentation of William Littlewood's Sixteenth Wright Brothers Lecture on "Technical Trends in Air Transport" by Otto E. Kirchner, American Airlines.

Jan. 7---Philadelphia Section: Joint I.A.S.-S.A.E. Meeting; Engineers Club of Philadelphia, 8:00 p.m. "Modern Military Helicopters" by Harry S. Pack, Vice President, Piasecki Helicopter.

Jan. 8---Los Angeles Section: Dinner Meeting; I.A.S. Building, Social Hour, 5:30 p.m.; Dinner, 6:30 p.m.; Lecture, 8:00 p.m. Presentation of William Littlewood's Sixteenth Wright Brothers Lecture on "Technical Trends in Air Transport" by Otto E. Kirchner, American Airlines.

Jan. 8---Texas Section: Specialists Meeting; Arlington State College, Arlington, Tex., 7:30 p.m. "Hypersonics" by Dr. R. Linnell, Convair's Fort Worth Division.

Jan. 9---San Diego Section: Dinner Meeting; San Diego Hotel, Dinner at 7:00 p.m. Presentation of William Littlewood's Sixteenth Wright Brothers Lecture on "Technical Trends in Air Transport" by Otto E. Kirchner, American Airlines.

Jan. 14---Buffalo Section: Touraine Hotel; Social Hour, 7:30 p.m.; Meeting, 8:00 p.m. "Rockets and Satellites" by Dr. Walter R. Dornberger, Missile Design Consultant to Bell Aircraft.

Jan. 14---Columbus Section: Dinner Meeting; Officers' Club at Port Columbus, 7:00 p.m. "Unusual Metals in Present and Future Aircraft" by Dr. Bruce W. Gonser.

Jan. 19---Boston Section: Room 35-225, Massachusetts Institute of Technology, 8:00 p.m. "European Aeronautical Ideas" by Dr. Jerome C. Hunsaker.

Jan. 20---Ottawa Aeronautical Society: National Research Council Auditorium, 8:15 p.m. "Air Photography in the North" by Wing Comdr. R. I. Thomas, A.F.C.

Jan. 21---Toronto Section: Room 254, Mechanical Engineering Building, University of Toronto, 8:15 p.m. "R.C.A.F. Research and Development" by Dr. J. J. Green, Deputy Chairman, Defense Research Board.

Jan. 21---Wichita Section: Joint I.A.S.-S.A.E. Meeting; Location and time of meeting not known at press time. "Complexity of Aircraft" by Capt. Walter S. Diehl, U.S.N.

Jan. 22---Los Angeles Section: Specialist Meeting on Adhesives and Metal Bonding; I.A.S. Building, 8:00 p.m. Speaker, Dr. N. A. de Bruyne, Aero Research, Ltd. England.

Jan. 22---San Francisco Section: Ramor Oaks, Redwood City, Calif., 8:00 p.m. "Activities at the Flight Safety Research Center" by Col. W. F. Yates, U.S.A.F., Director of Flight Safety Research Center, Norton A.F.B., San Bernadino, Calif.

Feb. 3---Washington Section: National Museum Auditorium, 8:00 p.m. Symposium on the Development of Turbine-Powered Transports.

Feb. 5---Chicago Section: Museum of Science and Industry, 8:00 p.m. Presentation of William Littlewood's Sixteenth Wright Brothers Lecture on "Technical Trends in Air Transport" by Otto E. Kirchner, American Airlines.

Feb. 17---Cleveland-Akron Section: Dinner Meeting; Location not known at press time; Dinner, 6:30 p.m.; Lecture, 8:30 p.m. "The Place for Naval Aviation Under the Influences of Supersonic Flight and Atomic Weapons" by Vice Adm. Paul Pihl, U.S.N.

* * * * *

Necrology

Wilbur R. Lindsey, Jr.

Captain Wilbur Ross Lindsey, Jr., U.S.A.F., was killed on October 7 when the U.S.A.F. C-47 transport that he was piloting crashed during an approach to the North Philadelphia Airport in submarginal weather conditions.

Born in Denton, Tex., on August 21, 1919, Captain Lindsey was graduated in 1935 from Corona (N.M.) High School and then went on to enroll in North Texas State College. He received his B.S. degree in Mathematics from North Texas State in 1947, after which he was sent to the University of Michigan where he took the specialized Guided Missile Course. In 1949, he received his M.S.E. degree in Aeronautical Engineering (Guided Missiles).

Captain Lindsey began his military career in January, 1943, when he enlisted as an Aviation Cadet. Upon the successful completion of his training, he was appointed a Second Lieutenant, A.U.S., and placed on active duty as a Flight Instructor in basic flight training. A short time later, he received transitional flight training in fighter-type aircraft and was assigned to the China-Burma-India theater where he accomplished 49 combat missions. Upon returning to the United States, he was awarded a commission in the regular army and was sent to North Texas State in September, 1946, to complete his requirements for the Bachelor of Science degree.

After completing his postgraduate work at Michigan, Captain Lindsey was assigned to Holloman A.F.B., N.M., as Missile Project Officer. In September, 1950, he was transferred and was entered in the U.S.A.F.'s 1-year missile training course with industry. When this training was ended, he was assigned to the 6555th Guided Missile Wing with permanent duty station at Holloman A.F.B. At the time of his death, Captain Lindsey was Officer-in-Charge of a missile test cadre.

Among the decorations and awards won by Captain Lindsey during his military career are the Air Medal with Two Oak Leaf Clusters and the Distinguished Flying Cross.

Captain Lindsey is survived by his wife, Alice Sue, two children, and his parents.

Presentation of The Thurman H. Bane Award

The Thurman H. Bane Award for 1952, given annually by the Institute of the Aeronautical Sciences in recognition of outstanding achievements in aeronautical development, was awarded posthumously to Major Patrick L. Kelly, U.S.A.F., at the I.A.S. Annual Summer Meeting Dinner on July 16.

On October 25 in ceremonies at the Air Research and Development Command's Wright Air Development Center, Dayton, Ohio, Major Kelly's widow, Mrs. Virginia O. Kelly, received the award from Brig. Gen. Albert Boyd, commanding general of W.A.D.C. The award consists of a citation and an honorarium of $200.

The award to Major Kelly, who was killed in an aircraft accident in November, 1951, was "for developing techniques providing for artificial stability and control of aircraft during high performance phases of aircraft operation." The system devised by Major Kelly incorporates the use of a combined control boost and automatic pilot. The control stability and maneuverability achieved by this system led to its adoption by the U.S. Air Force and represents an important advance in aircraft control.

At its Annual Summer Meeting Dinner, the I.A.S. also gave the 1952 Bane award individually to Henry Seeler, of W.A.D.C.'s Aero Medical Laboratory, for his development of a high-altitude respirator. (See page 17 of the August, 1952, issue of the REVIEW.)

The 1952 Thurman H. Bane Award: *Brig. Gen. Albert Boyd presents The Thurman H. Bane Award for 1952, granted posthumously to Major Patrick L. Kelly, to Mrs. Virginia O. Kelly.*

Booz, Allen & Hamilton Becomes New Corporate Member

The management consulting firm of Booz, Allen & Hamilton, a partnership founded in 1914 to assist managements in the attainment of their objectives and in the practical solution of problems in all phases of their operations, has joined the Institute of the Aeronautical Sciences as a Corporate Member. Booz, Allen & Hamilton is a charter member of the Association of Consulting Management Engineers, the central body representing the profession today.

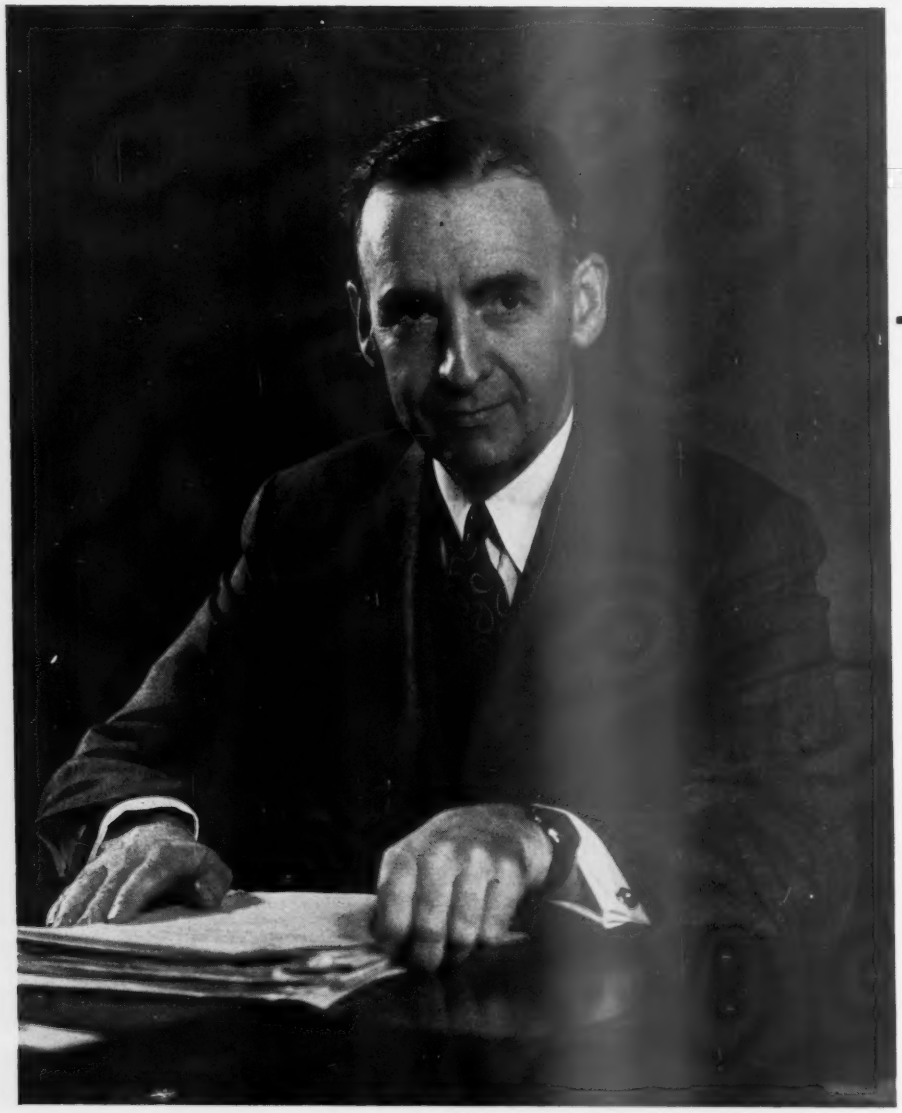
In recent years, the number of assignments completed by the firm in the field of aviation has increased substantially. This work has included assignments with major designers and producers of aircraft, aircraft power plants, and electronic and control equipment; programing of overhaul and maintenance activities; and evaluation of research and development programs. Considerable work is also carried on in the field of scheduled air transport. In addition to general organization and procedures surveys, the firm has developed a staff capacity for the performance of specific technical studies.

Besides industrial work, the firm of Booz, Allen & Hamilton has conducted extensive planning studies for the Armed Services in the fields of aircraft, jet and reciprocating power plants, guided missiles, and related systems.

Beyond its direct work in the aircraft field, the major part of the firm's volume continues to be with businesses, institutions, and Governmental bodies in all major areas of operations—general management, manufacturing, engineering and research, personnel, accounting and control, and sales. Numerous assignments have been handled in each size class—i.e., large, medium, and small.

Booz, Allen & Hamilton employs in its eight offices more than 350 people, over half of whom are professional consultants. Offices are located in New York, Chicago, San Francisco, Philadelphia, Washington, Detroit, Minneapolis, and Los Angeles.

(*I.A.S. News continued on page 62*)



I.A.S. President for 1953

CHARLES JOSEPH McCARTHY

Vice-President, United Aircraft Corporation; Fellow, Institute of the Aeronautical Sciences; Former Chief Engineer, Chance Vought Aircraft Company; U.S. Navy 1917–1926; Graduate, M.I.T., 1916.

Editorial

Hail—and Farewell

HONORS NIGHT (this year on January 26) is traditionally the occasion on which our officers for the coming year are inducted into office. The new President makes his first public appearance as such, and the retiring incumbent lays down the gavel.

Somewhat in advance of the event, we of the staff extend our heartiest welcome to our new Chief Executive and pledge to him our wholehearted cooperation for the year ahead. It will be a busy one. On top of the usual full program of I.A.S. meetings and other activities will be the Fourth International Aeronautical Conference with The Royal Aeronautical Society of Great Britain, now scheduled for the weeks of September 7 and 14 in London (see news story, page 15).

Our new President is well fitted to follow in the footsteps of Preston Bassett and Admiral Richardson who led I.A.S. Expeditionary Forces to England in 1947 and 1951. He is well known and well liked abroad, and his membership on the Institute's Council and Executive Committee in the past several years has given him an excellent insight into I.A.S. policies and programs. The Council has chosen well in electing him to the Presidency this year.

President McCarthy will be backed up by an able group of officers. I.A.S. Vice-Presidents for 1953 are George W. Brady, Director of Engineering, Propeller Division, Curtiss-Wright Corporation; C. L. Johnson, Chief Engineer, Lockheed Aircraft Corporation; James S. McDonnell, President, McDonnell Aircraft Corporation; and Ernest G. Stout, Staff Engineer of Convair. Preston R. Bassett, President of Sperry Gyroscope Company, will supervise I.A.S. finances, as Treasurer.

As is I.A.S. practice, our retiring President continues to serve the Institute as a member of the Council, usually as Chairman of our Executive Committee. Therefore, although Wellwood Beall steps down from the rostrum, we shall still benefit by the contributions he has made as 1952 President and will continue to make as a member of the Council. In spite of the long distance between Seattle and our National and Western headquarters and in spite of the tremendous claims on his time made by the current rearmament program, Past-President Beall has unstintingly made his services available to the Institute. His insight and appreciation of the problems of the engineer and his drive to bring more and better engineering talent to industry have left their mark. We all extend to him our thanks for a good job, well done. S. P. J.

I.A.S. Past-President

WELLWOOD E. BEALL

Senior Vice-President, Engineering and Sales, Boeing Airplane Company; Fellow, Institute of the Aeronautical Sciences.

Airplane Weight and Cost Can Be Reduced

*E. H. Heinemann**
Douglas Aircraft Company, Inc.

Introduction

There has been much talk recently about the alarming rising trend in aircraft weight, complexity, and cost. Most everyone concerned seems to be in favor of improving it, but many seem to be reluctant to do much about it for fear that something will be taken away from the military effectiveness of the airplane or that safety will be reduced.

This discussion is not pointed at any particular model or class nor at any particular tactical theory. This philosophy is merely one of looking at our entire air defense problem from the broadest point of view in an effort to influence engineering and procurement favorably toward obtaining the most effective and efficient airplanes.

Recent studies of some airplane designs have shown clearly that weight, complexity, and cost *can* be reduced, and, at the same time, combat effectiveness, the efficiency of the airplane and pilot as a team, and chances of survival can be improved considerably. As a result of these studies, it is believed that there are definite steps that can and should be taken and that, if all concerned pursue the problem vigorously, great gains can be made.

Recent Trends

First, however, it is important to realize the seriousness of these recent trends. Fig. 1 illustrates that, during the 50-year history of aviation, maximum velocity, which after all is the principal measure of the performance of aircraft, has increased at only 14 miles per year when expressed in terms of international speed records. Fighting machines have followed slightly behind these world speed records but for all practical purposes have followed a similar trend.

During this same period, however, it can be seen that the size of our machines, expressed in terms of weight, has increased at an alarming rate, as shown by Fig. 2. While a good deal of this weight growth can be charged to increased performance, I think it is generally agreed that the weight increase is disproportionate to the increase in performance. For example, the maximum speed at the end of the second quarter of this century has only doubled over that at the end of the first quarter, whereas the weight of our military machines has increased from 10 to 20 times.

The effect of weight growth is bound to reflect in complexity. There would be no argument against larger machines if performance, reliability, and military effectiveness would increase in a direct proportion to weight. Recent combat experience, however, has shown us that availability of airplanes in combat is inversely proportional to the amount of equipment they carry. And since equipment is at least directly proportional to airplane weight, a sure way to keep airplanes on the ground is to let them grow excessively in size.

The effect of recent design trends on cost is also most alarming. Fig. 3 illustrates that in 1930 $100,000,000 would buy slightly over 1,100 fighter airplanes, including Government-furnished equipment. In 1950 this number dropped to less than 100. In the bomber category $100,000,000 would buy approximately 400 airplanes in 1930 and at the present time will buy less than 20. This cost includes the development, tooling, construction, and Government-furnished equipment as nearly as can be determined from available figures.

Presented to the Washington Section, I.A.S., Washington, D.C., October 7, 1952.

* Chief Engineer, El Segundo Division.

One does not have to be an outstanding economist to see that this trend cannot be continued without tragic results to our national economy; for on one hand to demand a large number of air groups and on the other to permit unit costs to increase as they have is far from compatible or possible. Of course, some increase in cost is to be expected or we would not be making the proper progress. Still, it is up to us to control this situation rather than to let it control us.

Growth and Cost Factors

Perhaps one of the best ways to control this situation is to alert all concerned to some of the factors that result in these growth trends. Toward this end, the terms "airplane growth factor" and "cost growth" are used. Fig. 4 illustrates the term "airplane growth factor." This shows that if an airplane gross weight is increased by an increment of 10 per cent in the form of equipment weight added, then the wing area, power plant, fuel, and structure must be increased by 100 per cent, thus resulting in an airplane of twice the original gross weight if original strength and performance are maintained. If original strength and performance are not maintained, we are building an airplane with inferior performance, or, in other words, we are cheating our pilots in combat, as well as ourselves.

Of course, this growth factor of 10 will vary between types and models. The growth factor of many airplanes has been investigated and found to vary from the neighborhood of 5 for the older propeller-driven machines to 15 and 20 for some of the more modern high-performance fighters. Ten was used in this case inasmuch as it represented an average of several current efficient jet combat machines. It is therefore believed reasonable that designers of equipment, as well as airplanes, can be guided by using a growth factor of 10 in their design evaluations.

With respect to cost, Fig. 5 shows that each pound of weight added, when multiplied by a growth factor of 10 and a cost factor of $40 per lb., causes a $400 increase in airplane cost if performance, range, and strength remain constant. This $40 is a cost factor arrived at through many years of experience and is

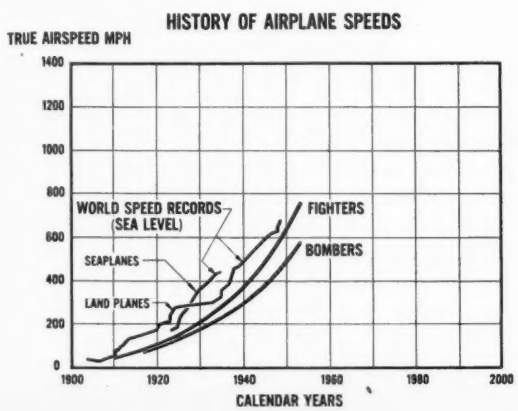
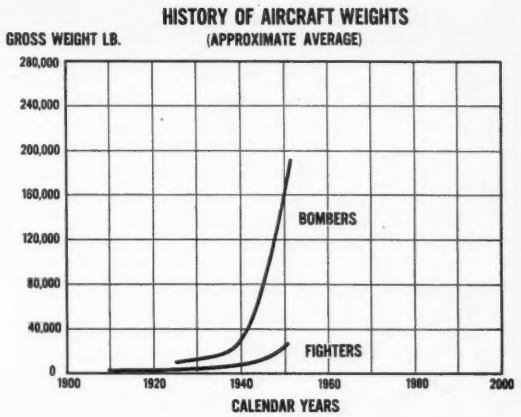


Fig. 1.



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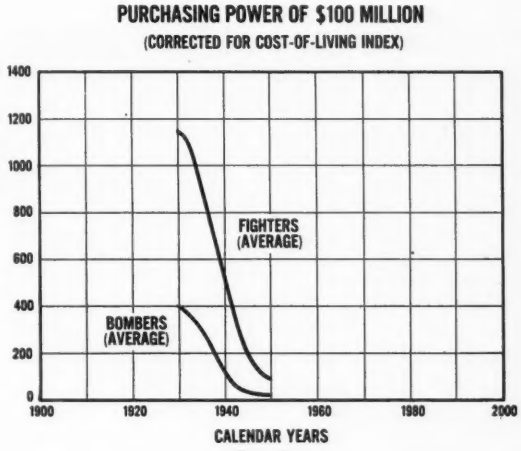

Fig. 3.

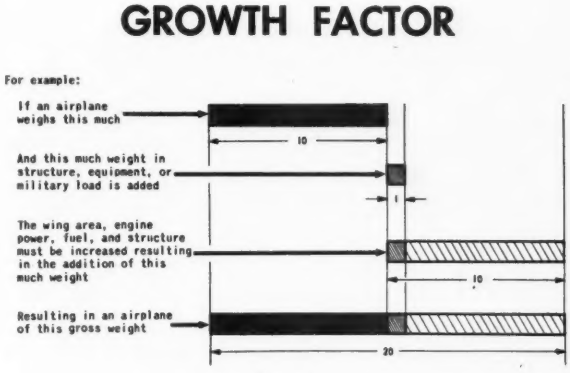
GROWTH FACTOR
For example:
If an airplane weighs this much
10
And this much weight in structure, equipment, or military load is added
1
The wing area, engine power, fuel, and structure must be increased resulting in the addition of this much weight
10
Resulting in an airplane of this gross weight
20

Fig. 4.

COST GROWTH
1 x 10 x $40 = $400.00
ONE POUND ADDED WEIGHT
GROWTH FACTOR
COST PER POUND
TOTAL INCREASE IN AIRPLANE COST
IF PERFORMANCE, RANGE AND STRENGTH REMAIN CONSTANT

Fig. 5.

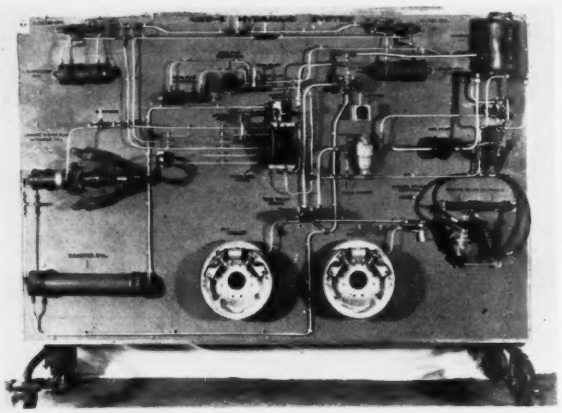

FIG. 6.

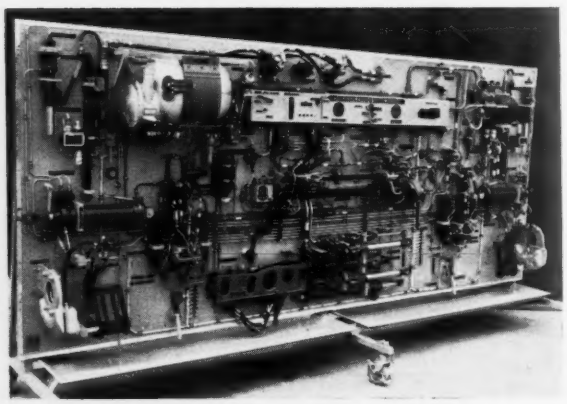

FIG. 7.

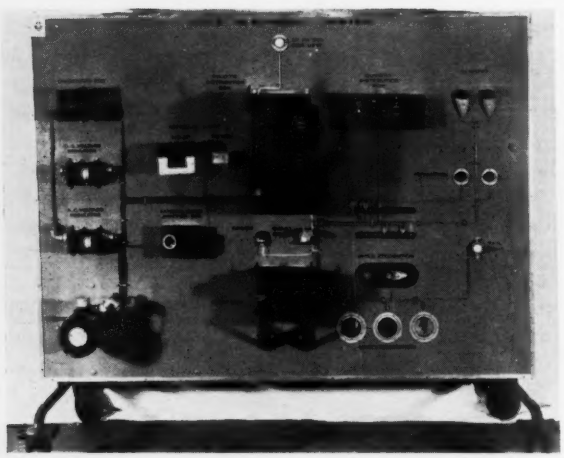

FIG. 8.

substantiated by the report *Survival in the Air Age* (Finletter Report for 1948). This cost represents experimental and production costs and is based upon gross weight, including Government-furnished equipment. It is rather arbitrary but, if anything, conservative. Recent spot-checks have shown that present costs are more likely to be nearer $50 per lb. Current statistics are not available to determine the actual costs. Nevertheless, it is recommended that designers and procurement agencies use a factor of $40 per lb. as a guide in evaluating design decisions.

GROWING COMPLEXITY OF AIRCRAFT

In spite of our best efforts to simplify and improve maintenance, airplanes persist in becoming more complicated because of the constant refinement of the science of aviation. For example, Fig. 6 illustrates the hydraulic system used on the well-known SBD Dauntless Navy dive bomber. This system consists of a reservoir, engine pump, emergency hand pump, selector valves for operating landing flaps, dive brakes, retractable landing gear, cowl flaps, and wheel brakes.

Compare this to the hydraulic system used on the AD Skyraider attack bomber (Fig. 7) which, by present standards, is one of the simplest in the business. A few functions have been added, as well as an accumulator and emergency devices, and it is a more efficient system. Still it can be seen clearly that its complexity and the number of parts subject to failure have increased considerably.

Fig. 8 shows the electrical system of the SBD Dauntless, excluding communicating and radar equipment. This system served the purpose well and, at the time, was considered quite satisfactory and easy to maintain.

Fig. 9 illustrates the electrical system of the AD airplane which is many times as complicated as the SBD. This also is understood to be one of the simplest systems in current use. It is evident that, here again, the efficiency of the system has increased, but the number of parts has increased so much that installation and maintenance are more difficult, failure of components more likely, and vulnerability to gunfire considerably greater.

There is obviously no hard and fast rule that can be applied to what is necessary and what is not in an aircraft, because aviation is made up of more conflicting requirements than probably any other business. Still there are many current requirements that should properly be considered as desirable rather than necessary. These borderline requirements are often just the difference between a successful and an unsuccessful airplane. If all of them are incorporated, it will probably be a bad machine. If they are carefully sifted and a minimum practicable number incorporated, it will probably be a good machine. A few of these questionable requirements are shown in Fig. 10. There are many others of a more minor nature. It is shown here that the nine particular items analyzed would weigh approximately 848 lbs. on an average fighter or attack-bomber airplane. The effect of this on cost weight, holding performance constant, would be 8,480 lbs., and the effect on cost to the taxpayer would be in the neighborhood of $339,000.

In many cases the attempt to try to satisfy all requirements results in an airplane so complicated that

the "point of no return" is reached, and, as a result of loss of performance and reliability, the pilot's chances of carrying out his objective are reduced rather than increased.

This does not imply that all of these items should be eliminated. In certain types of airplanes some are essential. Ejectable seats in most high-performance airplanes are no doubt a necessity. Still, two models of high-performance airplanes have been designed with equally effective escape chutes at little increase in weight and cost, and a third, as a result of such an analysis, has had its ejectable-seat weight reduced to less than half without sacrificing safety or reliability. This is a good example of how this reasoning can affect a designer's decisions favorably.

I would like to repeat that this design and procurement philosophy is not intended to decrease performance, combat effectiveness, quality, or the pilot's safety. Quite to the contrary, it is intended by inherent simplicity and a superior degree of design to improve combat effectiveness, performance, quality, and safety. This will no doubt require some additional design ingenuity, but it is believed to be well worth the price, since it will result in a larger quantity of superior airplanes for a given cost.

Conclusions

In conclusion, several specific methods for accomplishing this simplification are offered:

(1) Point out to all personnel having to do with aircraft design, requirements, and procurement the seriousness of this problem, with special emphasis on growth factor and cost.

(2) Review and re-evaluate specific requirements to determine their actual military worth and necessity.

(3) Review the design features and equipment during the preliminary stages of each new model from the point of view of what is best for the airplane as a whole rather than equipment or detailed requirements as they may have been established in the past.

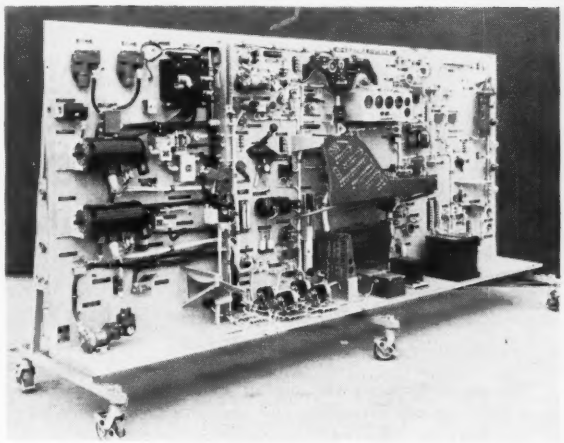

Fig. 9.

TYPICAL EXAMPLES OF EFFECT OF EQUIPMENT UPON G.W. AND COST

(TYPICAL FIGHTER)

ITEM	APPROX. WT. OF ITEM	EFFECT ON G.W.	EFFECT ON COST
WING DE-ICING	300	3000	120,000
BARRIER CRASH PROVISIONS	250	2500	100,000
AUTO PILOT	110	1100	44,000
STALL WARNING (MECHANICAL)	4	40	1,600
G LIMITER	20	200	8,000
JETTISONABLE SEATS	100	1000	40,000
DEHUMIDIFICATION OF COCKPIT	50	500	20,000
SINGLE POINT PEDAL ADJUST.	7	70	2800
AUTOMATIC INVERTER CHANGEOVER	7	70	2800
TOTAL	848 LB.	8480 LB.	$ 339,200

Fig. 10.

(4) Reduce complexity and weight by applying ingenuity to avoiding problems before they develop. From recent studies and actual airplanes designed in accordance with this philosophy, it is a positive fact that weight, complexity, and cost *can* and *must* be reduced.

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(See Special I.A.S. Publications, Page 33)

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Requirements for LARGE, LIGHT-METAL FORGINGS AND EXTRUSIONS in the Aircraft Industry*

Abstract

This paper discusses the aircraft industry requirements for large forgings and extrusions and supports these requirements by analyzing the effect of the trend in performance on aircraft structure, function, and production. The paper confirms that large integral structural components satisfy these trends better than a continuation of conventional "bits and pieces" structure. It further concludes that large forgings and extrusions are the most economical methods to produce integral-type structure.

In addition, detail requirements of large forgings and extrusions relative to physical properties, tolerances, and refinements are presented.

Statistical studies are presented to indicate the high potential use of large forgings and extrusions.

Introduction

THE AIR-FRAME MANUFACTURERS, forging, extrusion, and ingot producers, the press-building industry, and the Air Materiel Command have cooperated in programs aimed at the requirements of forgings and extrusions in modern and future aircraft design. Discussions of this program have appeared in the public press, technical press, and trade journals for several years. This paper has been prepared to gather together and summarize the various ideas that have been expressed and to restate the criteria that structural elements produced on large forging and extrusion presses must meet.

The Aircraft Research and Testing Committee, a subcommittee of the Aircraft Technical Committee, surveyed the industry on the question of large forgings and extrusions.[1] In this survey, practically all air-frame companies expressed a desire for large extrusions and forgings. Large forgings and extrusions for purposes of this survey were described as follows: *light-metal alloy forgings*—over 40 lbs. in weight or over 30 in. in length; *light-metal alloy extrusions*—over 10 sq. in. of cross-sectional area or over 10-in. diameter circumscribed circle or over 100 lbs. in weight.

The data submitted in answer to this survey were studied by a committee of forging producers. The findings of this group established beyond doubt the necessity for larger forging and extrusion equipment than is presently available. This was actually putting the final stamp of approval on a program, based on earlier surveys and studies, which was already under way. The highest capacity forging press in operation today is a mere 18,000-ton press. The new program provides 25,000-, 35,000-, and 50,000-ton presses. Maximum extrusion capacity under the new program will be 20,000 tons with presses graduated down in 12,000- and 8,000-ton capacities. The highest tonnage today is 5,600 tons.

Why did so many engineers in industry want large extrusions and forgings and larger extruding and forging presses? To answer this, the effect of the trend in aircraft performance on the structural, functional, and production design of air frames must be understood.

Trend in Aircraft Performance

An industry geared to the transportation of the world's people and goods must constantly improve. Reduced rates and increased efficiency can be obtained only by going faster and farther with heavier loads (Fig. 1).[2] Carrying more cargo, whether it be people, freight, or bombs, faster and farther requires constant development and research. Someone once said that lack of communication caused wars, and it must be accepted that lack of communication can lose one. Our peacetime commercial life depends on the efficient transportation of people and goods. Victory in war has always gone to the nation that delivered the most effective material and personnel to the right place in the shortest time.

Transportation is the life of the aircraft industry. Aircraft today are carrying heavier and bulkier loads faster and farther than ever before, and there is no

Presented at the Heavy Press Program for Light Metals, sponsored by the A.I.M.E., A.S.M.E., I.A.S., and S.A.E., New York, December 2, 1952.

* The information and background necessary in the preparation of this paper had been collected over several years of personal contact and experience with scores of industrialists, engineers, and technicians in the light-metal and aircraft industry. Individual acknowledgment for this excellent education in the economic and design problems involved in the use of large forgings and extrusions would require several pages. To list but a few companies and individuals that have played an important part is all that can be done. The Wyman-Gordon Company, Aluminum Company of America, Harvey Machine Company, Inc., Reynolds Metals Company, Kaiser Aluminum, Boeing Airplane Company, and Hydropress, Inc., have all contributed to the background needed to prepare this paper. Personal acknowledgment must be made to George Motherwell, Don Welty, A. H. Petersen, Dr. Hubert Altwicker, Ralph Moore, Karl Braeuninger, and William Schroeder for the personal attention they have given to my many demands for information and assistance.

† Manager, Production Engineering Department.

logical reason to assume that we have reached the limit. Transports in the supersonic speed range are still to come. Transports of sufficient efficiency to operate commercially nonstop from New York to London or Paris, or Los Angeles to New York, or many of the other standard long-distance routes are in the offing. These, we will have. These, we must have, and they can be obtained only by increased efficiency through flying faster and higher and farther with heavier loads. Increased speed, range, and pay load induce heavier loads on the structure of the airplane and require increased fuel capacity, greater useful load-carrying volume, and higher service ceiling. The higher service ceiling makes pressurization imperative.

In keeping with this continuous upward trend in performance requirements, renewed effort must be expended to maintain costs at a sufficiently low level so that cost per ton-mile is reduced by the increase in performance.

These performance trends will reflect themselves in one or more of the following ways on any given aircraft: (1) increased major overall dimensions; (2) higher structural loads; (3) increased aerodynamic smoothness requirements; (4) pressurization; and (5) thinner airfoil sections.

General Considerations

There are two ways to increase the load-carrying efficiency of a structural element, efficiency in this instance being measured by the weight of material required to support a given load. One of these is to use material with a higher strength-weight ratio. The other is more efficient distribution of the material used. Continual improvements are being obtained in the physical and mechanical properties of materials through alloying and refinement of metallurgical processes. Additional improvements can be made through mechanical processes. For example, the use of larger extrusion press cylinders and pressures will permit greater reduction ratios. These reduction ratios have a direct effect on the final physical properties of any given extrusion alloy.

The increased pressures available will make possible more efficient distribution of material through greater refinement of detail in both forgings and extrusions, thinner sections and closer tolerances, and less draft. All of the advantages of increased pressure are also available to reduce the weight and cost of smaller forgings and extrusions. This is an important consideration that is too often overlooked in the face of the more glamorous large extrusions and forgings.

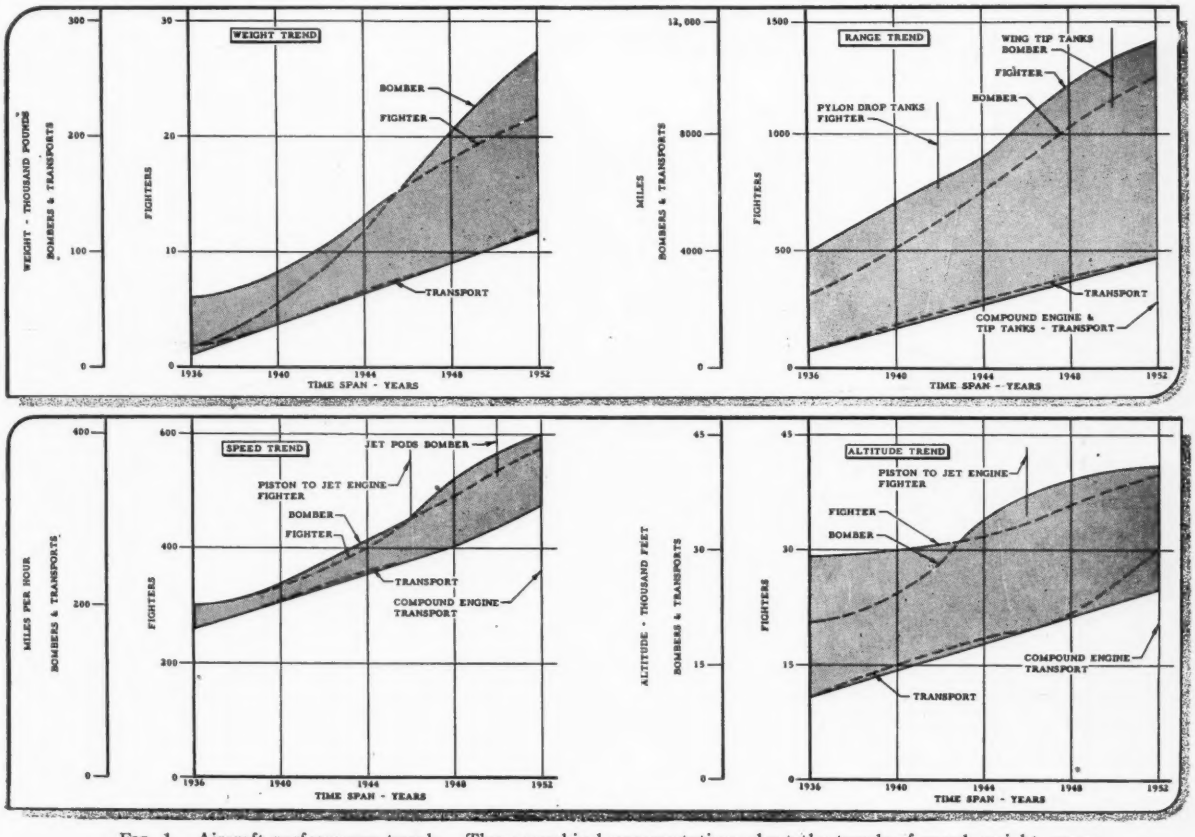


FIG. 1. Aircraft performance trends. These graphical representations chart the trends of speed, weight, range, and altitude improvement for fighter, bomber, and transport aircraft over the past 16 years. The points on the graph at which the most notable new developments affecting performance were introduced have been marked, and the development has been listed.

TABLE 1
Comparison per Airplane—Inner Wing Lower Surface—1049 Constellation

	Conventional Design, 120,000 Lbs. Gross Wt.	Integrally Stiffened Design, 130,000 Lbs. Gross Wt.	Savings	Savings over Conventional, Per Cent
Total number of detail parts	1,806	334	1,472	+81.5
Total attachments: rivets, screws, bolts, nuts, etc.	41,000	7,224	33,776	+82.4
Weight of sealant (lower portion of wing only), lbs.	80	30	50	+62.5
Total weight of structure including all parts and sealant, lbs.	1,736.9	1,442.4	294.5	+17.0

The conventional airplane structure can be increased in size by splicing on additional parts or by increasing the overall size of the parts. It is more economical weight- and cost-wise to double the size of skin sheets and plate than to obtain the increased surface area by splicing two or more sheets together. It appears more advantageous to use a one-piece 30-ft. wing beam produced by extruding or forging than by splicing two 15-ft. sections together. It is more advantageous to increase the cross-sectional area of a beam cap or bulkhead flange by increasing the dimensions than to obtain the additional area by laminating or "bits and pieces" build-up. Therefore, the dimensional growth, as well as the greater loads, can be most efficiently absorbed by the use of large forged and extruded elements.[3, 4] This combining of parts as opposed to bits and pieces construction has been labeled "integrally stiffened structure." To understand integrally stiffened structure is to know the primary reasoning behind large forgings and extrusions.

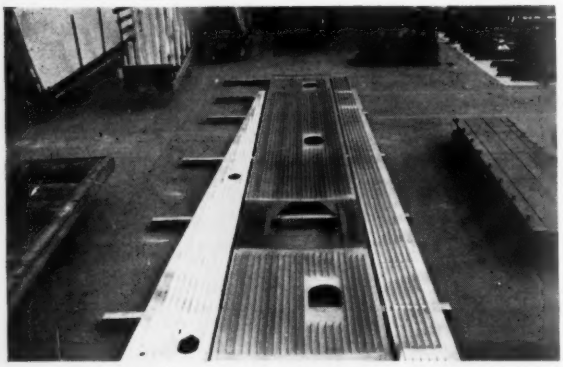


FIG. 2. Integrally stiffened wing skin panels. Of the three supplementary machined integrally stiffened wing skin panels shown, the center one is 32 ft. long and is the largest panel of this type so far machined. Examination of the photo discloses the cross-sectional variations possible with the machining approach. These variations compensate for net area effects and local attachment contingencies. The simple rectangular stiffener shape shown is a machining limitation, but integral construction allows the reduction of the spacing between stiffeners to provide more effectively for compressive loads.

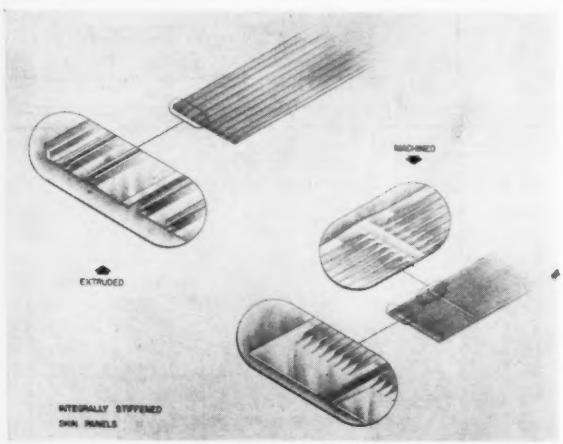


FIG. 3. Integrally stiffened skin panel details. The upper extruded skin pictorialization shows a typical extruded skin cross section and the excellent section properties possible by the extrusion method. A typical spanwise lap joint between extrusions is shown. The lower machined skin pictorialization shows the cross-sectional variations possible with the machined method to balance out local attachment contingencies. A tentative interpanel spanwise lap joint is also shown.

INTEGRALLY STIFFENED STRUCTURE

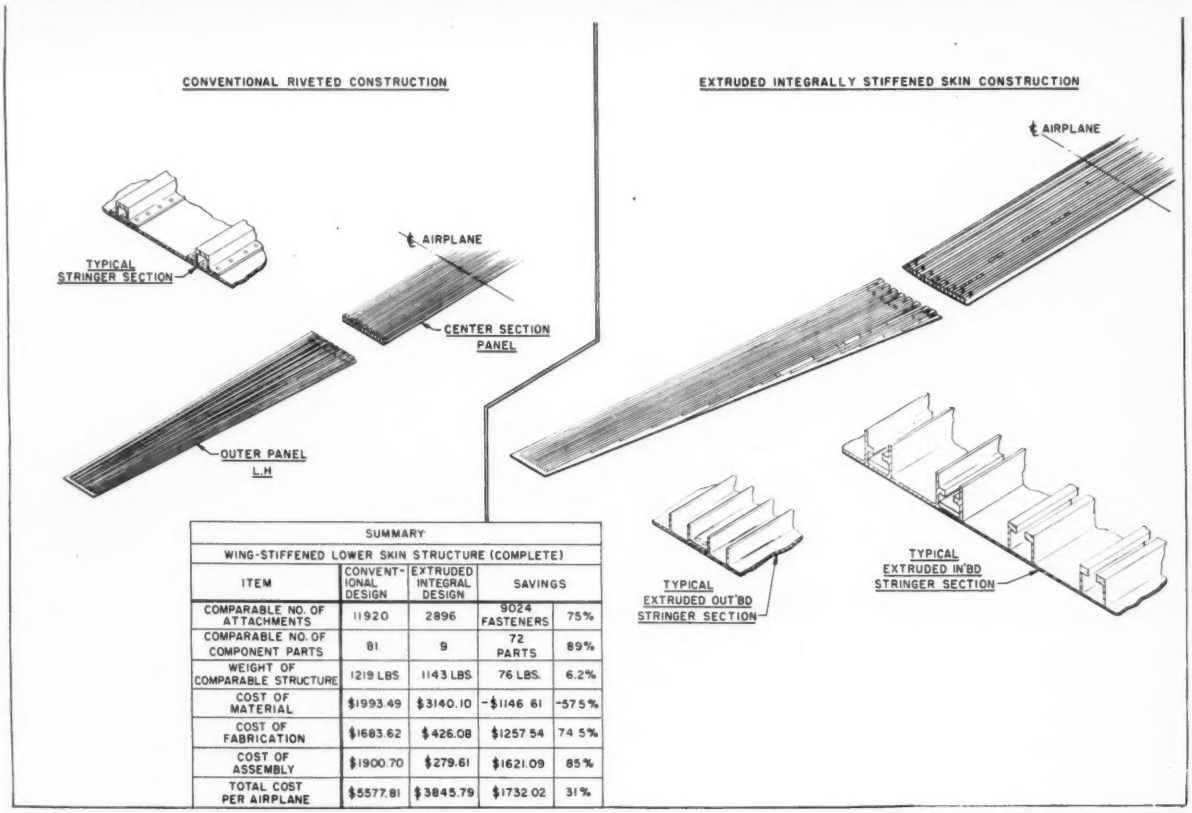
To meet the demands the performance trends indicate, larger wing, fuselage, and other components are needed. These new requirements in overall size, higher loads, and reduced overall manufacturing cost can best be obtained through integrally stiffened structure. To quote from a previous paper on this specific subject:[5]

"The name 'integrally stiffened structure' is applied to construction in which the skin and skin-stiffening elements are made of one part. This is in contrast with conventional structure, which is built-up of many individual fabricated sheet-metal parts held together by a multitude of attachments.

"There are several methods of making integrally stiffened structure. It may be machined from plate or billet, or it may be forged, or rolled as a sheet product, or extruded, or cast—or may be made by a combination of these processes.

"The immediate advantages of such a structure are the reduction in number of parts and attachments and the reduction in handling expenses and assembly tooling. Other advantages also are generally obtained, such as reduced weight, improved surface smoothness, and simplified sealing."

The Super Constellation inner lower surface is an excellent example of integrally stiffened structure. Table 1 is a breakdown of the differences between the conventional bits and pieces approach and the integrally stiffened structure now used (Fig. 2).



SUMMARY				
WING-STIFFENED LOWER SKIN STRUCTURE (COMPLETE)				
ITEM	CONVENTIONAL DESIGN	EXTRUDED INTEGRAL DESIGN	SAVINGS	
COMPARABLE NO. OF ATTACHMENTS	11920	2896	9024 FASTENERS	75%
COMPARABLE NO. OF COMPONENT PARTS	81	9	72 PARTS	89%
WEIGHT OF COMPARABLE STRUCTURE	1219 LBS	1143 LBS.	76 LBS.	6.2%
COST OF MATERIAL	$1993.49	$3140.10	-$1146 61	-57.5%
COST OF FABRICATION	$1683.62	$426.08	$1257 54	74 5%
COST OF ASSEMBLY	$1900.70	$279.61	$1621.09	85%
TOTAL COST PER AIRPLANE	$5577.81	$3845.79	$1732.02	31%

FIG. 4. Integrally stiffened wing skin structure comparison. A comparative examination of the relative merits of conventionally stiffened skin construction versus extruded integrally stiffened skin construction is made with the resulting data listed above. The wing joint shown is assumed to be of equivalent efficiency in both design alternatives.

The extruded integrally stiffened skin has one marked superiority over the machined type in that it permits the incorporation of the more efficient "T" or "L" stiffened section, which, when considered independently, permits about an 18 per cent increase in allowable column loading because of the more efficient cross-sectional material distribution.[6, 7] Nevertheless, this does not represent the whole story, since currently available extruded sections cannot taper or vary in cross section, as machined sections can, to correspond to local loading conditions and to compensate for net area reductions due to splices or attachment holes (Fig. 3).

Therefore, it is not possible to generalize that one is superior to the other. You can apply their qualifications only to the problems of specific designs to determine which should be used.

However, when we consider these integral types in comparison with the standard assembled stiffened skin construction, we find them in clear structural superiority (Figs. 4, 5, and 6).

For one thing, there are definite practical limits to the closeness of the spacing of the attached stiffeners. Because of this, only about 80 per cent of the skin area can be really effective in skin gages in customary use, whereas with the integral type, we can achieve a 100 per cent skin working area.

An additional important consideration is the unavoidable overlap in stiffener attachment areas and the inherent reduction in net area due to stiffener and other attachment holes which is an accepted corollary to assembled construction but eliminated wherever integral structure can be applied.

This same thinking can be applied to beams, spars, bulkheads, flooring, ribs, and other structural components. The structural advantages of integral structures are found in more efficient distribution of material, fewer splices, less material removed for attachment holes, all of which result in less weight.

A section property comparison of a forged integral wing beam with a standard built-up beam of extruded cap strips and a shear resistant web of plate stock shows that the attachment holes of the web assembly to cap strip and to upright stiffener can reduce the structural efficiency of the web.

In any comparison of integral wing-beam construction with the conventional extruded cap-strip type, we must keep in mind the fact that these extruded machined tapered cap strips are in themselves limited examples of integral construction which comprise up to 90 per cent of the beam cross-sectional area.

Consequently, because of the high efficiency of this type of semi-integral construction, we do not get as sharp a definition of the advantages of the proposed

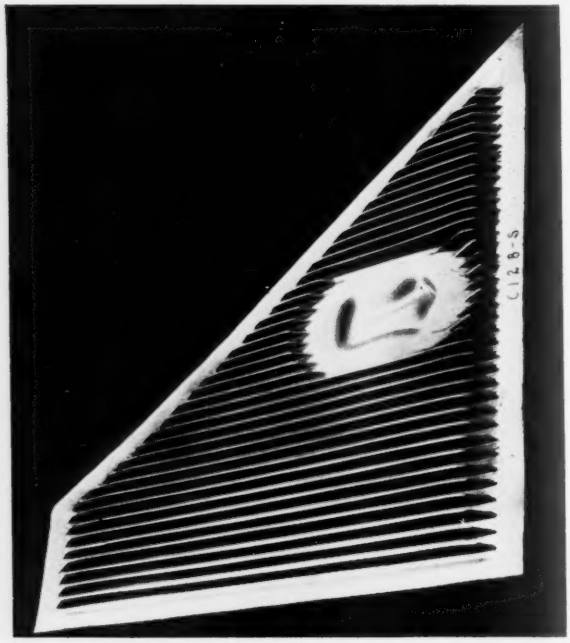


FIG. 5. Forced integrally stiffened skin panel. This experimentally forged integrally stiffened aluminum-alloy skin panel was formed on an 18,000-ton forging press.[8] Skin gages as low as 0.1 in., with 1.00-in. stiffener height, were obtained with considerably lower forging pressures than anticipated. Inspection of the photo gives an approximate idea of the "as-forged" dimensional alignment and the finish now possible by means of press forging.

100 per cent integral construction here as we are able to achieve elsewhere. This is particularly true in the 12 per cent of chord thickness wing and holds until we progress to the thinner wings approaching, say, 3 per cent of chord in thickness. Here, genuine integral construction shows overwhelming advantage.

The net area reduction of attachment holes in thin wings and the necessary overlaps in attachment areas can reduce web efficiencies as expressed in the C_r rivet factor by 50 per cent. Also, the intermittent splices

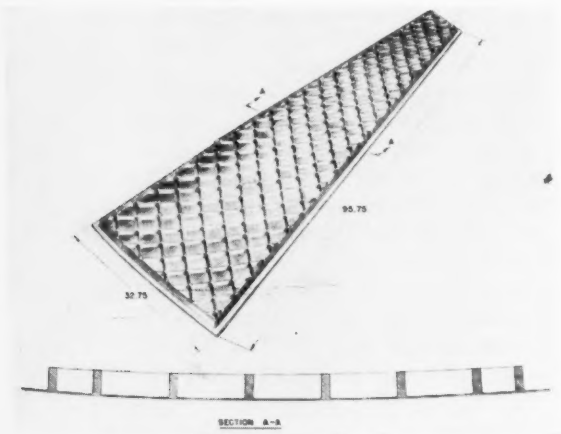


FIG. 6. Forged waffle pattern integrally stiffened skin panel. The illustration depicts overall dimensions and waffle arrangements for a 75S forged panel. Relative proportions are also shown.

necessary to tailor web gages to decreasing stress requirements as the wing tapers toward the tip further reduces efficiency.

Fig. 7, a shear-flow diagram of the web of a beam of conventional construction as opposed to integral construction, gives pictorial proof of the extra weight required by inefficient distribution of material in bits and pieces construction. The shaded area represents the difference in weight between efficient and inefficient distribution of material. Integral construction avoids all this by providing material of exactly the right cross section when we need it and where we need it—devoid of overlap eccentricities—and precisely corresponding to local attachment contingencies and stress requirements. A typical forged beam design is illustrated in Fig. 8.

This line of reasoning also applies to ribs, bulkheads, floor supports, and other internal structural members. Many bolts, rivets, and bits and pieces can be eliminated through use of large integral elements (Figs. 9, 10, and 11).

The smoothness of a finished aerodynamic surface is proportional to the stiffness of the skin between stiffening elements, type of substructure, number and type of attachments through the skin, and the number of surface joints. Integrally stiffened structure, by combining the skin with the substructure (doublers, stiffeners, and formers) making possible closer stiffener spacing, also reduces the number of attachments and number of surface joints, all of which lowers the sources of surface irregularities and increases the probability of satisfactory aerodynamically smooth surface. Trailing edges and other secondary structure comprising an aerodyamic surface are usually excellent places to realize the advantages of integral stiffening.

Sealing of integral fuel tanks and pressurized areas is simplified. Sealing is required only in proportion to the number of joints and number and type of attachments through the pressure wall, whether this be skin, bulkhead, rib, or spar webs. Integral structure reduces the number of joints, attachments, and faying surfaces, which in turn reduces the amount of sealing material and man-hours required to seal the structure either for fuel retention or pressurization.

PRODUCTION CONSIDERATIONS

The general application of large integral elements offers many important possibilities for cost reduction. However, of even greater importance, increased performance and weight reduction appear feasible without increased cost. Many instances of direct man-hour and tooling-cost savings have been developed. The most apparent and readily acceptable savings are in indirect labor. Production control, stocking, inspection, transportation, and tool planning are almost directly proportional to the number of different parts manufactured (Fig. 12). Assembly labor and assembly tooling are proportional to the number of parts that

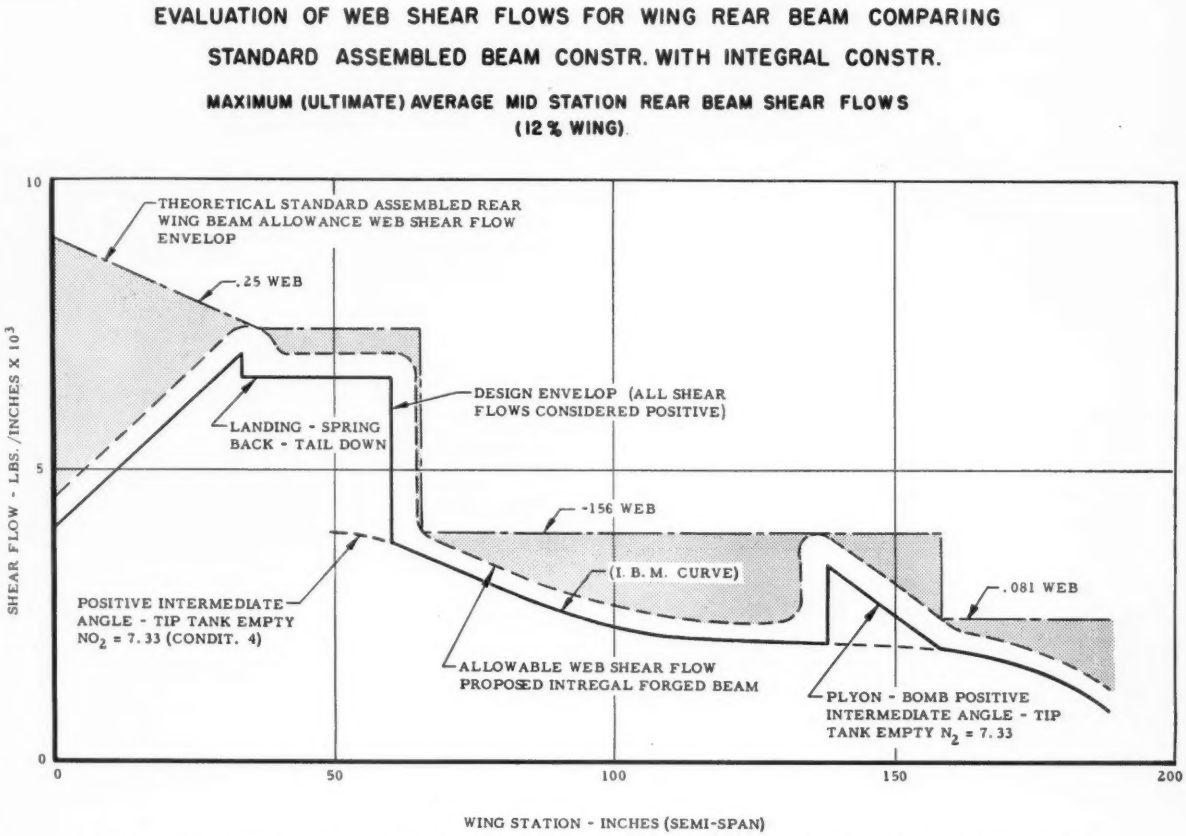

EVALUATION OF WEB SHEAR FLOWS FOR WING REAR BEAM COMPARING
STANDARD ASSEMBLED BEAM CONSTR. WITH INTEGRAL CONSTR.
MAXIMUM (ULTIMATE) AVERAGE MID STATION REAR BEAM SHEAR FLOWS
(12 % WING)
THEORETICAL STANDARD ASSEMBLED REAR WING BEAM ALLOWANCE WEB SHEAR FLOW ENVELOP
.25 WEB
DESIGN ENVELOP (ALL SHEAR FLOWS CONSIDERED POSITIVE)
LANDING - SPRING BACK - TAIL DOWN
.156 WEB
(I. B. M. CURVE)
.081 WEB
POSITIVE INTERMEDIATE ANGLE - TIP TANK EMPTY NO2 = 7.33 (CONDIT. 4)
ALLOWABLE WEB SHEAR FLOW PROPOSED INTREGAL FORGED BEAM
PLYON - BOMB POSITIVE INTERMEDIATE ANGLE - TIP TANK EMPTY N2 = 7.33
SHEAR FLOW - LBS./INCHES X 10³
WING STATION - INCHES (SEMI-SPAN)
10
5
0
0
50
100
150
200

FIG. 7. This shear-flow graph shows the increase in web efficiency possible with tailored integral structure over conventional assembly construction.

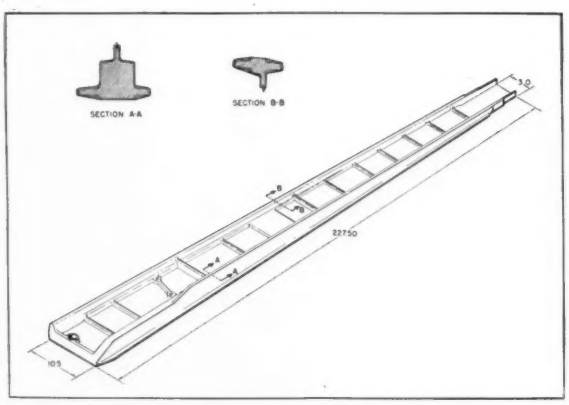


FIG. 8. Forged aluminum-alloy wing rear beam. This depicts current forged beam thinking, which calls for adapting conventionally assembled beam features to integral thin web forged construction.

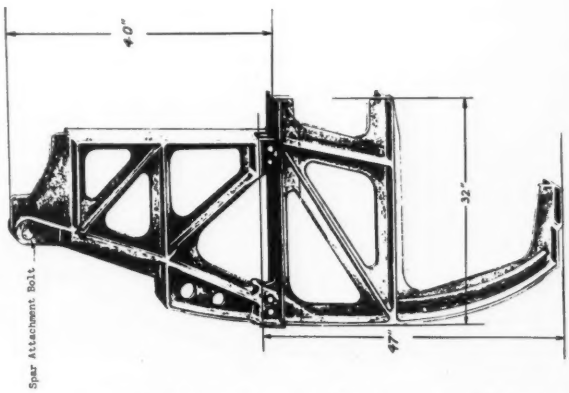


FIG. 9. 14S aluminum-alloy bulkhead station 425 forging assembly. This depicts the larger integral-type forging with thin wall structural members and large web cutouts. The material distribution here calls for relatively large forging area with minimum volume.

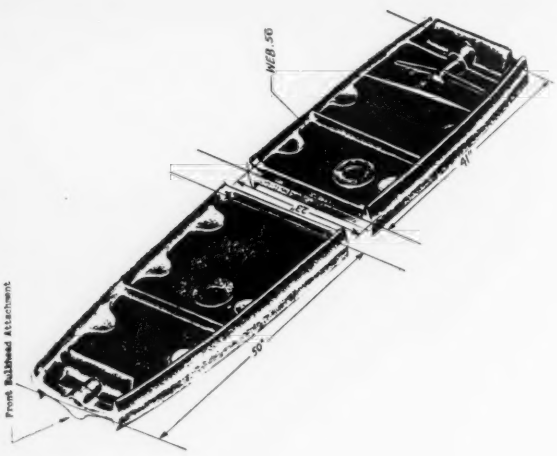


FIG. 10. Forged 14S aluminum-alloy wing root rib station 425. This depicts the larger type of conventional forging cut in the middle to keep forged units within the maximum capacity of the available forging facilities. This type of forging characterizes one phase of current thinking and practice in this field.

must be assembled. In many instances, savings in fabrication hours and tooling are apparent through a reduction in the number of different parts to be manufactured. Large elements eliminate much of the bits and pieces of manufacture and result in direct gains wherever the number of different pieces to be handled affects the cost. When structures consisting of presently available forgings, extrusions, and sheet stock are redesigned to take advantage of integral structure, incorporating into one element the many individual pieces, savings in overall manufacturing hours are realized.

TABLE 2
Reinforced Skin Sump Tank Structure

Item	Conventional	Integral Extruded	Savings	
No. of comparable attachments	2,684	1,084	1,600 Fasteners	60%
No. of comparable component parts	217	141	76 parts	35%
Comparable costs	$586	$486	$100	21%
Weight in pounds of reinforced skin	25.5	19.28	6.2 lbs.	24%
Weight in pounds of comparable tank structure	60.7	54.45	6.2 lbs.	10%

Fuselage sump tank, Fig. 13, is an example of the use of extruded integrally stiffened structure. The combining of skins and stiffeners in this instance reduces sealing material and man-hours by eliminating attachments. Combining skins and stiffeners eliminates the assembly time required to drill and rivet the attachments. Reduction in number of parts reduces all indirect and direct operations affected by the number of different parts to be manufactured (see Table 2).

The machining of mating surfaces between caps and end fittings, caps and webs, and landing gear, flap, and aileron support fittings is eliminated. The reduction in surface attachments rivets, screws, and bolts, which must be countersunk, dimpled, milled, and filled with smoothing compounds, reduces direct labor and increases surface flushness to a greater extent than current smoothing techniques.

WHY FORGINGS AND EXTRUSIONS?

Integral structure may be obtained by rolling, casting, hogging from plate or billet, forging, or extruding.

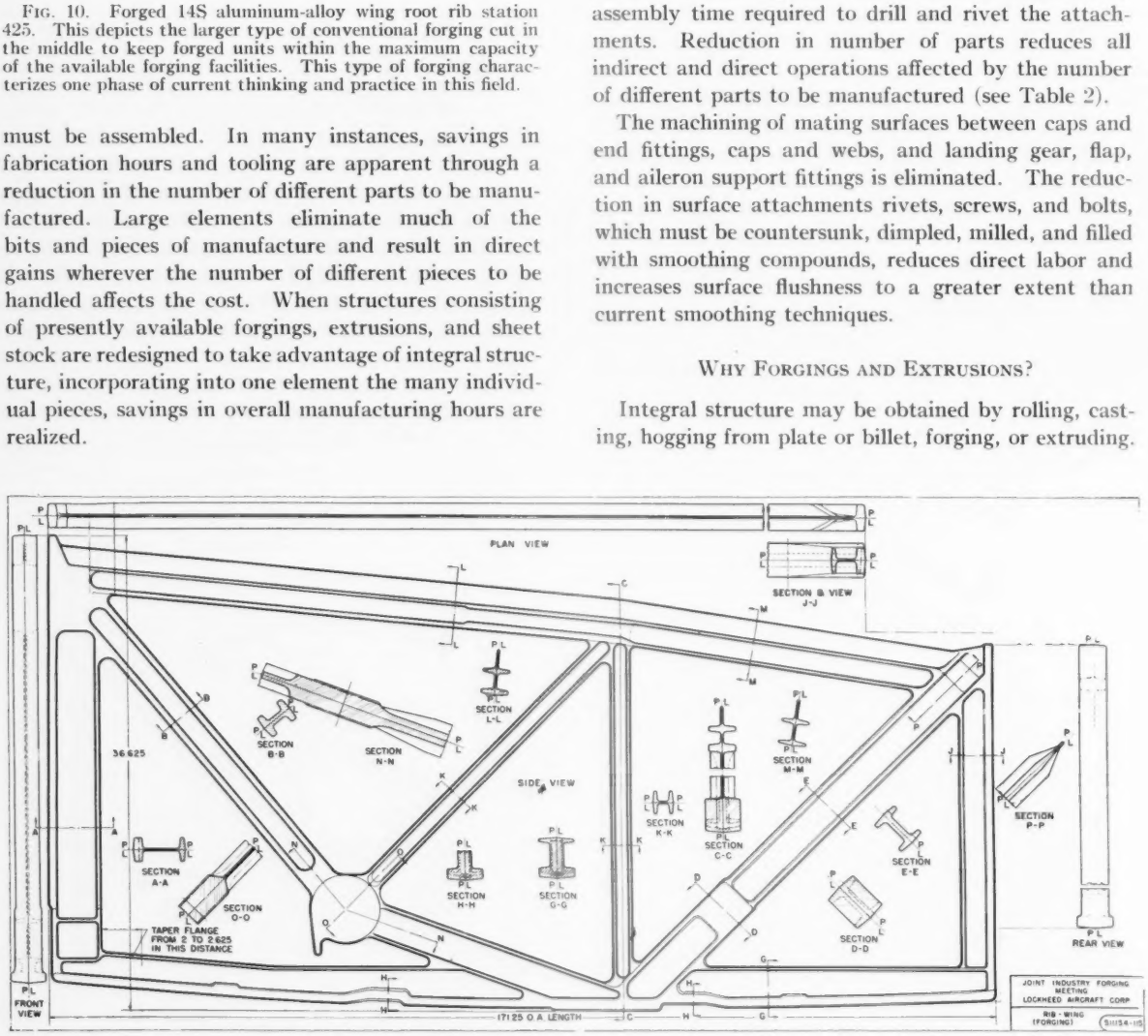


FIG. 11. Integrally forged 75S wing inboard rib. Drawing discloses design details and relative proportioning of a forged wing rib with integral provisions for landing-gear retraction fittings. This integral forging has been designed to replace a complex and expensive assembled structure of machined components—components that are of forged, wrought, or extruded origin.

Why, then, all the emphasis on large forgings and extrusions? Hogging or machining from plate or billet requires tremendous machines and many machine-hours. A part machined from plate or billet is not as consistent in its mechanical properties as a part forged or extruded to finished or nearly finished dimensions. Mechanical properties in the center of thick plate or billet are questionable. Forgings have the added advantage of variable grain direction that can generally be tailored to the stress patterns of a specific design. The large percentage of stock going into chips is unfavorable (Figs. 14–15). Casting materials do not have sufficiently high physical properties, nor have casting techniques developed to the point where efficient metal distribution and thin sections can be obtained. Castings cannot be considered for primary structural elements until a casting technique is developed which will eliminate the casting design factor now required. Improvement in casting alloy physical properties to values that can adsorb this factor and still compete with the wrought alloys is also needed to improve their potential use.

Each of these forms has certain areas where it has some advantages over the others, but, for overall usefulness and general application, the most efficient structures for the lowest cost appear to result from large forged and extruded elements.

Large Forgings and Extrusions —Quality

The large forgings and extrusions needed to accomplish and fulfill successfully the design and production requirements induced by the trend in performance of aircraft must be better in many respects than the forgings generally available today. The methods for obtaining some of these improvements in forgings have been a source of much research and development. This work must continue—specifically in the fields of:

Draft Angles must be held to a minimum. Practically all material contained in draft reduces the efficiency of the section. There are occasions when draft angle can be used to advantage in design. However, generally speaking, as forgings get larger, the per cent of draft material, using present standards, would reflect itself in tremendous and objectionable overweight. It must be eliminated during the forging process, not by machining in the air-frame plant. Draft angles, even in those few cases where weight is not paramount, may interfere with mating surfaces. Also bolts, nuts, and other fasteners must have relatively flat surfaces to bear against. It is not economical to consider machining the inside faces of bulkheads and ribs, for example, to remove draft to provide flat bolt pads. It is not practical at this time to establish or accept any standard draft angle; suffice it to say that draft angles of 1°, 3°, and 5° must be made available.

Tolerances also reflect an increase in weight or expensive machining operations. Here again, no specific tolerance can be or should be established at this time. The greater precision of presses over hammers, the

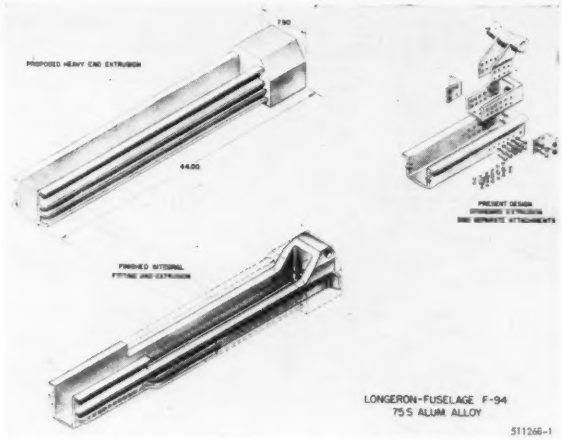


Fig. 12. 75S aluminum-alloy fuselage longeron. This illustration makes clear the clean logical simplicity of integral design with its absence of multiplicity of attachments and detail parts.

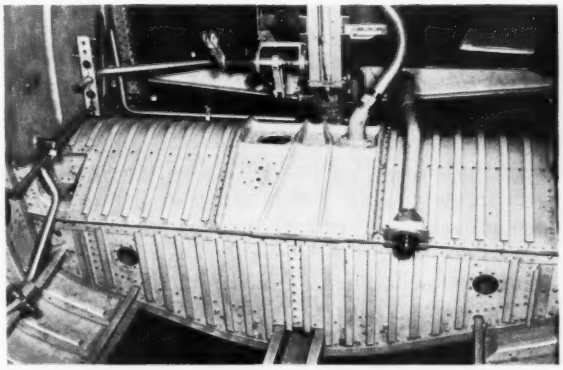


Fig. 13. Sump tank with extruded integrally stiffened skins. The photo shows design details common to integral construction with the reduction in component parts and various fasteners clearly discernible. Further, the standards of workmanship possible with this construction are also illustrated.

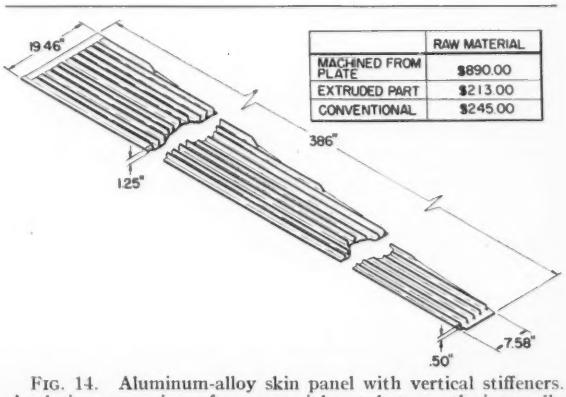


Fig. 14. Aluminum-alloy skin panel with vertical stiffeners. A relative comparison of raw material costs between the integrally stiffened types and the conventionally stiffened panel is set forth.

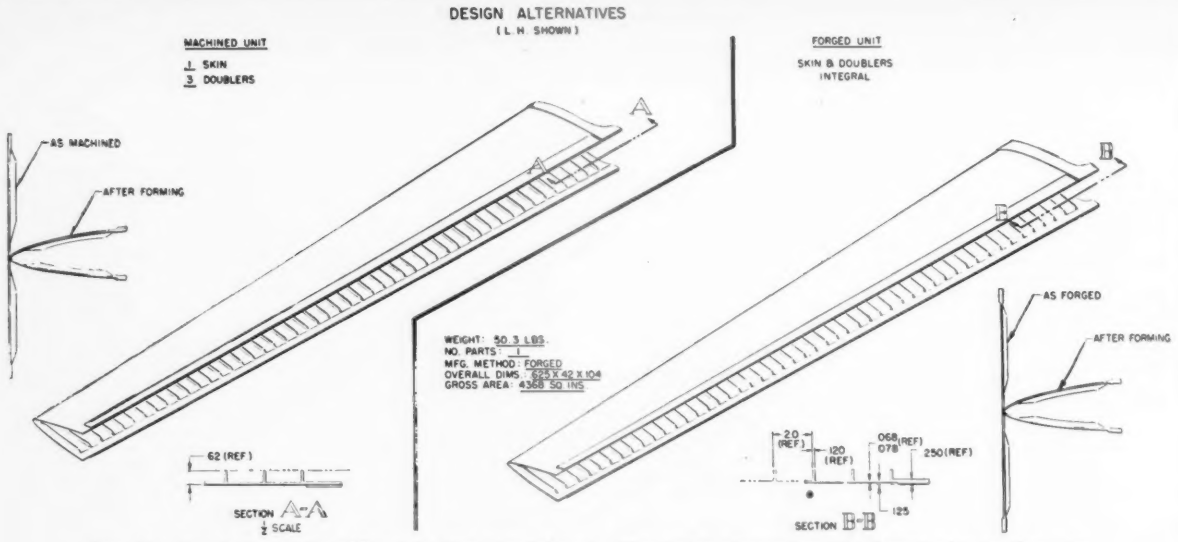


FIG. 15. Panel—integrally stiffened leading edge inboard. The design alternatives of a forged wing leading edge versus a machined wing leading edge are relatively evaluated.

elimination of high impact or shock loads, the use of die holders, and the practical application of internal heaters permitting close control of temperature are the technological reasons why close tolerances can be obtained. Forging draft and tolerances can require rework of as much as 288.6 lbs. from a 400-lb. forging before it is satisfactory for aircraft. Tolerances in the extrusion field are primarily a matter of improvement in die material and precision of diemaking and accurate control of the extrusion operation.

Refinement of Section—Forgings and Extrusions with thinner webs or sections, greater ratio of section thickness differences, greater ratio of stiffener, leg, or protuberance height to thickness, and reduced fillet and corner radii are available through the increased pressures available, as well as the technological advances noted in the previous section.[8]

Procurement Time both in the original order and in subsequent changes—and there will be changes—will have to be timed to meet the requirements of the constant effort of the air-frame industry to reduce delivery time on the finished product. Large forged and extruded elements must be designed into the prototype. Present efforts to reduce prototype spans on many models to 18 and 24 months make it mandatory that forgings and extrusions be available in no more than 6 to 9 months from placing of order. It may be necessary to establish a die block material pool in addition to arriving at some solution to the shortage of die sinkers in training, both of which are potential bottlenecks.

UTILIZATION OF FORGINGS AND EXTRUSIONS

The potential application of large forgings and extrusions and of higher pressures to smaller forgings and extrusions is tremendous. For example, extrusions represent 17 per cent of the raw stock of a fighter airplane by weight, 23 per cent of the raw stock of a patrol bomber, and 8.5 per cent of a commercial transport. The per cent of raw forging stock to the other stock by weight for the same airplanes is 3.5 for fighter, 2.2 for patrol bomber, and 0.8 for commercial transport.

The increased pressure available increases the physical properties, decreases web thicknesses, reduces tolerances, and permits greater definition, thus opening a fairly extensive field for immediate application.[9]

As to the application to new structures such as skins or bulkheads or increasing the use of conventional structures like beams and spars, the following statistics are of interest. The surface structure between the beams of the wing and between the beams of the stabilizer of a patrol bomber is 8.6 per cent of the air-frame weight (Aeronautical Monthly Progress Report definition); on a transport, 7.7 per cent; and on a fighter, 7.6 per cent. This then represents a possible 7.9 per cent increase in usage. If leading edges, ribs, and bulkheads are added to this, a really tremendous potential market is open for development.

One of the major questions involved in establishing the requirements for tool and diemaking facilities is the effect of the great number of changes which apparently takes place in aircraft. The retention of forgings and extrusions through various major design changes can best be illustrated by a few statistics. During the period from 1948 to 1952, the F-80 series went through five model changes. During this time and through these revisions, an excellent retention of extrusions and forgings was maintained (see Tables 3 and 4). What happened during this same period to some of the conventional elements that we now propose to make as forgings and extrusions?

The wing surface of this same fighter, consisting of aluminum-alloy skins supported by extruded stringers and formers and doublers riveted thereto, did not change sufficiently to require new extrusions through five model changes and in over 2,300 airplanes. Since the trend

in any specific aircraft is always toward increased performance, the structural changes are always in the direction of increased load. Therefore, had any changes taken place in these structures, it would have been to increase the size, which in most instances could have been handled in the same forging or extruding dies. In those cases where total replacement was necessary, it was almost always with another forging or extrusion (see Tables 3 and 4).

TABLE 3
Retention of Aluminum-Alloy Extrusions on a Fighter Airplane

Period	Total Used	Quantity Retained	% Retention
1948	202	202	100
1949	196	194	96.0
1950	203	167	82.7
1951	210	161	79.7
1952	307	89	44.1

TABLE 4
Retention of Aluminum-Alloy Forgings on a Fighter Airplane

Period	Total Used	Quantity Retained	% Retention
1949	48	48	100
1950	54	43	89.5
1951	58	42	87.5

SUMMARY

It is difficult to summarize a collection of this type of data unless it is assumed that all of the prognostications will come about. If this assumption is accepted, the following summary is in order:

The trend in aircraft performance will result in a tremendous use for large forgings and extrusions, because large forgings and extrusions should be the most economical method of (1) meeting the space limitations set up in thin wings with high structural loads; (2) providing minimum weight by eliminating bits and pieces; (3) improving sealing for pressurization and fuel by eliminating sources of leakage; (4) improving aerodynamic smoothness; and (5) reducing man-hours required to fabricate and assemble aircraft.

The final answer as to whether large forgings and extrusions will be used is the cost in national effort which must be expended to obtain them as finished parts in an airplane successfully accomplishing its mission. This necessitates that the cost of the forging or extrusion, plus any subsequent operations on the part of the air-frame builder to make an acceptable part, require a smaller expenditure of national effort than any other means of accomplishing the same result.

Only the combined cooperative efforts of the entire forging and extrusion industry, from press designers through ingot producers through forging and extrusion producers and to and through the air-frame manufacturers, can accomplish all the promising gains to be had through the use of large forgings and extrusions.

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How to Buy Aluminum Castings

FLOYD A. LEWIS*
The Aluminum Association

Introduction

With some 2,800 foundries throughout the United States casting aluminum, buying aluminum castings might seem like one of the easiest things to do. Actually, it is a matter that may involve a number of headaches because many foundries are not properly equipped to produce quality products. During periods of restricted metal supply, it is particularly important that castings be purchased from foundries that can make the most efficient use of available metal.

A good procedure to follow is outlined in the accompanying "Twelve Rules for Buying Aluminum Castings." The twelve steps are not always followed in exactly the order listed, and sometimes there is overlapping between two or more steps. But all of these points should be given careful consideration, especially if the castings involve any unusual features.

If the part to be cast is a simple one involving no special requirements or high mechanical strength, the purchase is greatly simplified. Almost any foundry that can produce castings of good appearance may be selected. Any complications in the design or in structural or other requirements, however, must be given careful attention if difficulties are to be avoided. Except for the simplest parts, it is not wise to buy on the basis of bid price alone, since any one of a number of possible difficulties may wipe out any apparent saving in purchase price.

The first thing the purchaser must do is to estimate how many units will be required, because this will largely determine the casting process to be used. He must then ascertain the mechanical and physical requirements that the part must meet so that a suitable alloy can be chosen. These steps are closely interrelated because only certain alloys are adaptable to each of the various casting methods.

Other factors that will influence choice of casting process are the size and shape of the part, minimum sectional thickness, dimensional tolerances, surface finish, and relative machining and finishing costs.

Choosing the Casting Process

About 90 per cent of all aluminum castings now being produced are made by the sand, permanent-mold, or die-casting processes. A comparison of these methods is given in Table 1.

In sand casting, a pattern of the required shape and size to produce the desired part is molded in sand, the mold being broken to extract the casting and the pattern being remolded for each unit produced. In permanent-mold casting, the metal is poured in cast-iron or steel molds which are so constructed that the mold may be opened and the casting removed. Any necessary cores are also made of cast iron or steel. Die castings also are produced in metal molds, or dies; but, whereas in permanent-mold casting the metal flows into the mold cavity by gravity, in die casting it is forced into the cavity under pressure. Both the dies and cores are constructed of heat-treated alloy steel.

Sand casting is the most flexible of the three methods and is generally employed for large or intricate castings and for castings of all types and sizes where the quantity to be produced will not justify the construction of a metal mold or die. Sand casting also is used for longer production runs of small and medium-sized parts of a design suitable for modern high-speed molding equip-

Table 1

Comparison of Sand, Permanent-Mold, and Die Castings

	Sand Castings	Permanent-Mold Castings	High-Pressure Die Castings
Strength	2	1	2(a)
Structural density	2	1	3
Reproducibility of successive castings	3	2	1
Pressure tightness (after machining)	2	1	2
Cost per piece (b)	3	2	1
Speed of production (b)	3	2	1
Flexibility as to alloys	1	2	3
Tolerances	3	2	1
Flexibility of design	1	2	3
Size limitation	1	2	3
Surface	3	2	1
Speed of getting into production	1	2	2
Pattern or mold cost	1	2(c)	3(d)
Thickness of section	3	2	1

Ratings 1, 2, and 3 indicate the relative advantages of the three methods for each factor, number 1 being the most advantageous.

(a) Thin die castings of uniform section may have first classification in the "as cast" condition.

(b) Although this rating covers the majority of castings, in some cases either sand or permanent-mold castings may take first place.

(c) The cost of permanent-mold equipment may be equal to or less than production sand-cast equipment for large or complicated castings adaptable only to these two processes.

(d) The cost of dies plus the cost of tooling for machining or finishing is frequently less than the same overall cost for sand or permanent-mold castings.

* Editor.

TABLE 2

Composition of Commercial Aluminum Casting Alloys

Alloy Designation* New	Alloy Designation* Old	Nominal Composition, Per Cent, Balance Aluminum — Copper	Silicon	Magnesium	Zinc	Nickel	Others	Heat Treatable	Sand, Permanent-Mold or Die
C4A	C1	4.5	..	..	..	..	..	Yes	S
CG100A	CG1	10.0	..	0.25	..	..	..	Yes	S & P
CN42A	CN21	4.0	..	1.5	..	2.0	..	Yes	S & P
CS42A	CS4	4.5	2.5	..	..	..	..	Yes	P
CS43A	CS5	4.0	3.0	..	1.0	..	..	Yes	S
CS104B	CS21	10.0	4.0	1.0	..	1.0	..	No	P
CS72A	CS22	7.0	2.5	..	2.5†	..	..	No	S & P
CS66A	CS23	6.5	5.5	0.4	..	..	..	Yes	P
G4A	G1	..	..	4.0	..	..	..	No	S
G8A	G2	..	..	8.0	..	..	..	No	D
G10A	G3	..	..	10.0	..	..	..	Yes	S
GS42A	GS1	..	1.8	4.0	..	..	..	No	S & P
GZ42A	GZ1	..	..	4.0	1.8	..	..	No	P
S5A	S1‡	..	5.0	..	..	..	..	No	S & P
S5B	S2‡	..	5.0	..	..	..	..	No	S & P
S5C	S4‡	..	5.0	..	..	..	..	No	D
S12A	S9**	..	12.0	..	..	..	..	No	D
SC64A	SC1	4.5	5.5	..	..	..	..	No	P
SC54A	SC2	3.5	5.0	..	..	..	..	No	D
SC54B	SC5**	3.5	5.0	..	..	..	..	No	D
SC84A	SC6**	3.5	8.5	..	..	..	..	No	D
SC84B	SC7	3.5	8.5	..	..	..	..	No	D
SC64B	SC8	3.7	6.3	..	1.0†	0.5†	..	Yes	S & P
SC64C	SC9	3.7	6.3	0.5	1.0	0.5	0.8Mn	Yes	S & P
SC51A	SC21	1.3	5.0	0.5	..	..	..	Yes	S & P
SC122A	SC41	1.5	12.0	0.7	..	..	0.7Mn	Yes	P
SC82A	SC42	1.5	7.8	0.4	..	0.2	0.4Mn	Yes	S
SG70A	SG1	..	7.0	0.3	..	..	..	Yes	S & P
SG100A	SG2**	..	9.5	0.5	..	..	..	No	D
SN122A	SN41	1.0	12.0	1.0	..	2.5	..	Yes	P
ZG61A	ZG41	..	..	0.6	5.5	..	0.5Cr	Yes	S

* From specifications of American Society for Testing Materials.

† Maximum values.

‡ Alloys S5A and S5B are identical except that impurities in S5A are held to lower limits, giving it greater resistance to corrosion. S5C is a similar alloy for die casting.

** Impurities in these die-casting alloys are more closely controlled than in the other die casting alloys of otherwise identical composition. These alloys can be cast only in cold-chamber machines.

ment where costs lower than for other methods can be established.

Both permanent-mold and die-casting processes are inherently mass-production methods. They are, therefore, particularly useful where large numbers of identical castings are to be produced. No specific lower limit can be established at which these processes become economical. Usually several thousand units must be required to make either process feasible, although as few as 500 have been produced economically in special cases.

In general, permanent-mold castings have higher mechanical properties, greater uniformity, smoother surfaces, closer dimensional tolerances, and better pressure tightness than sand castings. By taking full advantage of these factors, castings made by this method will usually require less metal for the same design stress than sand castings. The smoother surfaces and closer dimensional tolerances mean lower machining and finishing costs.

Many designs that are too intricate to be produced from a practical standpoint by the full permanent-mold process can be successfully cast using iron molds and sand cores. This combination results in what is known as the "semipermanent" mold method, extending the flexibility of the permanent-mold process while retaining many of its advantages.

Ability to cast thin sections, accuracy, uniformity of reproduction, and low unit cost characterize the die-casting process. In reproduction of surface detail and surface finish, die casting is superior to any other method. The thinner sections possible with this method permit substantial savings in metal. The dimensional accuracy, smooth surfaces, and ability to cast threads and core holes contribute to minimum finishing cost.

Two basic types of die-casting machines are in use—the so-called "gooseneck" and "cold-chamber" machines. In the former, air pressures up to about 750 lbs. per sq.in. are utilized; pressures ranging from about 3,000 to more than 20,000 lbs. per sq.in., produced hydraulically, are employed in the cold-chamber machine. Because of the superiority of the castings produced at the higher pressures, gooseneck machines are gradually disappearing in favor of the cold-chamber units.

Sand castings weighing from a few ounces up to 1,500 lbs. are commonly produced, and castings up to 7,000 lbs. have been made by this process. Permanent and semipermanent mold castings from a few ounces to 300 lbs. in weight are in regular production, but permanent-mold castings weighing up to 500 lbs. have been produced. For die castings, the weight range is from a fraction of an ounce up to about 20 lbs. Die castings having overall dimensions up to 36 by 12 by 9 in. are being produced, but the dimensions in one direction may exceed these, die castings up to 84 in. in length having been produced.

A few parts can best be produced by other methods, such as the plaster-mold process, investment or "lost

TABLE 3
Mechanical Properties of Aluminum Casting Alloys (Typical Values)

	CONDITION[1]					TENSION[3]			COMPRESSION[6]	HARDNESS[3]	SHEAR	FATIGUE
Alloy (ASTM Designations)	As-Cast	Annealed	Artificially Aged	Solution Heat Treated	Solution Treated & Aged	Yield Strength (Set = 0.2%) Psi.	Ultimate Strength Psi.	Elongation, % in 2 In.	Yield Strength (Set = 0.2%) Psi.	Brinell, 500-Kg. Load, 10-Mm. Ball	Shearing Strength, Psi.	Endurance Limit[5] Psi.
C4A	-	-	-	S	-	16,000	32,000	8.5	16,000	60	24,000	6,000
C4A	-	-	-	-	S	30,000	40,000	2.0	38,000	95	31,000	7,000
CG100A	-	S	-	-	-	20,000	27,000	1.0	20,000	80	21,000	9,500
CG100A	-	-	-	-	S	30,000	40,000	0.5	43,000	115	29,000	8,500
CG100A	-	-	P	-	-	35,000	37,000	0.5	40,000	115	27,000	8,500
CG100A	-	-	-	-	P	36,000	48,000	0.5	36,000	140	30,000	9,000
CN42A	-	S	-	-	-	18,000	27,000	1.0	18,000	70	21,000	6,500
CN42A	-	-	-	-	S	25,000	28,000	2.0	-	75	24,000	9,500
CN42A	-	-	P	-	-	34,000	40,000	1.0	34,000	105	26,000	10,500
CN42A	-	-	-	-	P	42,000	47,000	0.5	46,000	110	31,000	9,500
CS42A	-	-	-	P	-	22,000	37,000	9.0	22,000	75	30,000	9,500
CS42A	-	-	-	-	P	26,000	40,000	5.0	26,000	90	32,000	10,000
CS42A	-	-	-	-	P	20,000	39,000	4.5	20,000	80	-	-
CS43A	S	-	-	-	-	14,000	19,000	1.5	-	-	-	-
CS104B	P	-	-	-	-	24,000	32,000	1.5	32,000	100	22,000	-
CS72A	S	-	-	-	-	15,000	24,000	1.5	17,000	70	20,000	9,000
CS72A	P	-	-	-	-	19,000	28,000	2.0	19,000	70	23,000	-
CS66A	-	-	P	-	-	16,000	29,000	1.0	16,000	95	22,000	-
G4A	S	-	-	-	-	12,000	25,000	9.0	12,000	50	20,000	5,500
G8A	D	-	-	-	-	27,000	45,000	8.0	27,000	-	27,000	23,000
G10A	-	-	-	S	-	25,000	46,000	14.0	26,000	75	33,000	7,000
GS42A	S	-	-	-	-	13,000	20,000	2.0	15,000	50	17,000	-
GZ42A	P	-	-	-	-	16,000	27,000	7.0	17,000	60	22,000	-
S5A	S	-	-	-	-	9,000	19,000	6.0	10,000	40	14,000	6,500
S5B	S	-	-	-	-	9,000	19,000	6.0	10,000	40	14,000	6,500
S5A	P	-	-	-	-	9,000	24,000	9.0	9,000	45	18,000	-
S5B	P	-	-	-	-	9,000	24,000	9.0	9,000	45	18,000	-
S5C	D	-	-	-	-	16,000	30,000	9.0	16,000	-	19,000	17,000
S12A	D	-	-	-	-	21,000	39,000	2.0	21,000	-	25,000	19,000
SC64A	P	-	-	-	-	16,000	28,000	2.0	16,000	70	25,000	-
SC54A	D	-	-	-	-	24,000	40,000	5.0	24,000	-	26,000	22,000
SC54B	D	-	-	-	-	22,000	38,000	5.5	22,000	-	25,000	22,000
SC84A	D	-	-	-	-	25,000	46,000	3.0	25,000	-	29,000	19,000
SC84B	D	-	-	-	-	26,000	45,000	2.0	26,000	-	29,000	20,000
SC64B	S	-	-	-	-	18,000	27,000	2.0	18,000	70	-	10,000
SC64B	-	-	-	-	S	24,000	36,000	2.0	24,000	80	-	10,000
SC64B	P	-	-	-	-	19,000	34,000	2.5	19,000	85	24,000	-
SC64B	-	-	-	-	P	27,000	40,000	3.0	27,000	95	-	-
SC64C	S	-	-	-	-	18,000	23,000	-	-	-	-	-
SC64C	-	-	-	-	S	24,000	31,000	1.5	-	-	-	-
SC64C	P	-	-	-	-	19,000	26,000	-	-	-	-	-
SC51A	-	-	S	-	-	23,000	28,000	1.5	24,000	65	22,000	7,000
SC51A	-	-	-	-	S	25,000	35,000	2.5	29,000	80	30,000	8,500
SC51A	-	-	-	-	S	29,000	35,000	1.5	-	75	-	10,000
SC51A	-	-	-	-	P	27,000	43,000	4.0	27,000	90	30,000	9,000
SC122A	-	-	-	P	-	27,000	41,000	2.5	27,000	90	-	-
SC122A	-	-	P	-	-	26,000	40,000	0.3	26,000	97	-	-
SC122A	-	-	-	-	P	38,000	43,000	1.0	38,000	92	-	-
SC82A	-	-	-	-	P	40,000	49,000	3.0	-	97	-	-
SC82A	-	-	-	S	-	20,000	33,000	2.9	20,000	82	-	-
SC82A	-	-	-	-	S	28,000	36,000	2.0	28,000	81	-	-
SG70A	-	-	S	-	-	20,000	25,000	2.0	22,000	60	18,000	7,500
SG70A	-	-	-	-	S	24,000	33,000	4.0	24,000	70	27,000	8,000
SG70A	-	-	-	-	P	27,000	40,000	5.0	24,000	90	-	-
SG100A	D	-	-	-	-	27,000	44,000	3.0	27,000	-	28,000	19,000
SN122A	-	-	P	-	-	28,000	36,000	0.5	28,000	105	24,000	-
SN122A	-	-	-	-	P	43,000	47,000	0.5	43,000	125	27,000	-
ZG61A	-	-	S[2]	-	-	25,000	32,000	3.0	25,000	75	26,000	9,000

1. In these columns S denotes specimen cast in green sand; P denotes chill-cast specimen having properties similar to a permanent or semipermanent mold casting; D denotes die cast specimen.

2. May be aged at room temperature, or artificially aged at higher temperature.

3. Tension and hardness values determined from standard half-inch diameter specimens individually cast in sand (S) and permanent (P) molds, and tested without machining off the surface. Tension values for die casting alloys determined from standard 1/4-inch die cast specimens (D); hardness values are not shown for die castings because they cannot be reliably determined.

4. Yield strength is the stress which produces a permanent set of 0.2% of the initial gage length American Society for Testing Materials Standard Methods of Tension Testing.

5. Endurance limits are based on 500,000,000 cycles of completely reversed stress using the R. R. Moore type of machine and specimen.

6. Compression tests made on specimens having an l/r ratio of 12.

wax" method, and centrifugal casting. Parts requiring smoother surfaces and greater accuracy than can be obtained with any of the three principal processes may be successfully cast in plaster molds. Some of the intricate parts of automatic automotive transmissions which require great accuracy are being successfully produced by this method. The investment process is also capable of great accuracy and is sometimes used for extremely small complicated parts that can be produced in groups or clusters. Aluminum pipe is successfully cast by the centrifugal method, as well as a number of other parts of special character.

If the part to be produced requires the use of one of these specialized methods, it is best to discuss the problem directly with one or more of the foundries using the particular method in question. Since these foundries are relatively few in number, their selection is comparatively easy.

Selecting an Alloy

After the casting method best suited to the design and production requirements has been determined, an alloy suitable for that method which will have the necessary properties may be chosen. Sometimes it is difficult to find an alloy that will have all the desired characteristics. Often the final choice will narrow down to one representing the best compromise between two or more conflicting factors.

Commercial aluminum casting alloys in common use today are listed in Table 2. Their mechanical properties are given in Table 3, which also indicates the processes with which they can be used. In Table 4, these alloys are grouped by the broad general types of application for which they are most suitable.

The first decision to be made in choosing an alloy is whether one not requiring heat-treatment will provide the necessary mechanical and other properties or whether a heat-treated alloy will be required. As shown in Table 3, heat-treatment increases the strength but often lowers ductility. Die-casting alloys are not usually given any heat-treatment except aging treatments at relatively low temperatures.

Although tensile strength is perhaps the most significant single mechanical characteristic to be considered, an alloy should not be chosen on the basis of that property alone. Yield strength, elongation, hardness, and compressive, shear, and fatigue strengths are other mechanical characteristics that may be significant in any particular application.

Attention must also be given to the casting qualities. For simple designs where high strength is not a factor, the casting qualities do not require any special consideration; but, if the design is complicated or if the castings must be pressure tight, an alloy having good casting qualities should be used.

If the castings will be exposed to corrosive elements such as acids or salt water, then one of the alloys having high resistance to corrosion should be used. Machinability is a characteristic that should receive careful consideration for castings requiring considerable machining. While ease of machining and finishing is one of the outstanding characteristics of aluminum castings in general, some alloys machine more easily than others.

Where the castings must retain their strength at elevated temperatures, such as those used in internal-combustion engines, one of the alloys possessing this characteristic must be used. Some engine parts require good resistance to wear in addition to high strength at elevated temperatures. Pistons, for example, require this combination of properties plus good casting and machining characteristics.

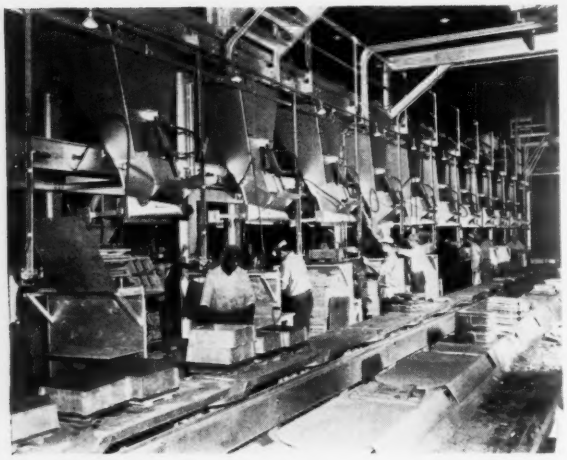
In applying the values given in Table 3 to an actual design, it must be borne in mind that those values are based upon tests made on carefully cast test bars. In some castings these characteristics may not be fully realized. For example, in castings involving thick sections, the unit mechanical strength will be lower than that shown by the test bars. Likewise, in castings having thinner sections, the unit mechanical strength may be higher than in the separately cast test bars.

Alloys containing copper and silicon, either singly or together or in combination with smaller amounts of other elements, comprise the groups that are most widely used for the great bulk of aluminum casting production. In addition, these alloys cover a wide range of mechanical properties so that they are useful for some of the more specialized purposes as well.

Table 4
Classification of Aluminum Casting Alloys by Type of Application

Class	Casting Method: Sand	Permanent-Mold	Die
General-purpose alloys	C4A CS43A SC64B SC64C ZG61A	CS42A SC64B SC64C	S12A SC54A SC84B SG100A
General-purpose alloys where pressure tightness is required	CS72A S5A SC51A SG70A	CS72A S5A SC64A SC51A SG70A	SC84B SG100A
Alloys for architectural and decorative purposes	S5A G4A GS42A SG70A	S5A GS42A GZ42A SG70A	G8A S12A SG100A
Alloys with high resistance to corrosion	S5A S5B G4A G10A GS42A SG70A	S5A S5B GZ42A SG70A	G8A S5C S12A SG100A
Alloys retaining strength at elevated temperatures*	CG100A CN42A SC51A SC82A	CG100A CN42A SN122A SC51A CS104B SC122A	SC84A SC84B SG100A
Piston alloys	CG100A CN42A	CG100A CN42A CS66A SN122A SC122A	SC84B

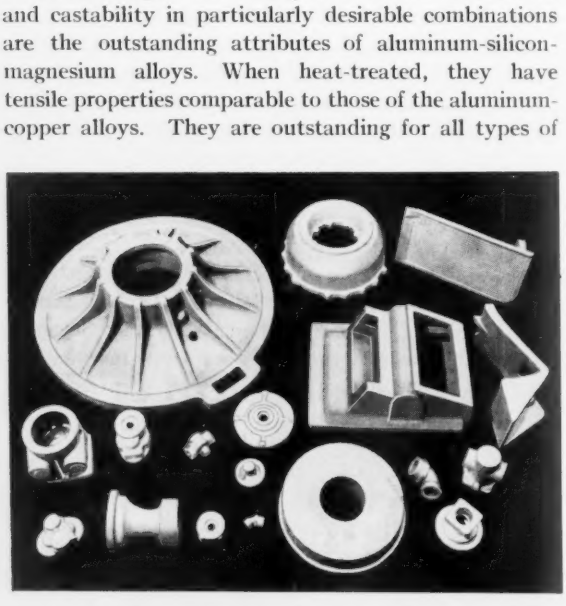
* When service temperatures are above 600°F., die castings may develop surface blisters.



Molding room in an aluminum sand foundry.

The aluminum-copper-silicon alloys have better casting characteristics than the aluminum-copper alloys but are not as resistant to corrosion as the aluminum-silicon series. The copper content provides strength and hardness, while the silicon content improves the casting qualities and increases the resistance to corrosion. These alloys are particularly well adapted to casting work involving intricate design, having large differences in section thickness, or requiring pressure tightness. Excellent casting characteristics are found also in the aluminum-silicon alloys, together with higher resistance to corrosion. For these reasons, there is an increasing trend toward the use of aluminum alloys in which silicon is a major alloying element. Although the machining of these alloys is more difficult than that of many other aluminum alloys, the problem is simplified by proper technique, tools, and lubricants.

Pressure tightness, strength, corrosion resistance, and castability in particularly desirable combinations are the outstanding attributes of aluminum-silicon-magnesium alloys. When heat-treated, they have tensile properties comparable to those of the aluminum-copper alloys. They are outstanding for all types of service requiring high-quality castings, especially those of intricate design.



Typical aluminum-alloy sand castings.

Resistance to atmospheric corrosion and exceptional castability are the two prime requisites for alloys to be suitable for architectural and decorative purposes. The aluminum-silicon and aluminum-magnesium alloys stand highest on the list in corrosion resistance, and the aluminum-silicon series has excellent casting characteristics that enable them to reproduce faithfully fine design details. The aluminum-magnesium series has higher resistance to corrosion, but the casting qualities are not so good.

Aluminum-silicon alloys are widely used in marine work because of their excellent resistance to salt water and salt-laden atmospheres. Although the aluminum-magnesium series is much more corrosion resistant, these alloys are not used so widely because of their difficult casting characteristics. By adding other elements, such as silicon or zinc, the casting properties are somewhat improved. The aluminum-silicon alloys, however, are superior in mildly acid solutions such as those found in the textile industry. Both series find extensive applications in the food-handling and chemical industries.

Many special-purpose alloys have been developed for applications where specific characteristics are desired. Their usefulness, however, usually is limited to the particular applications for which they are designed. Typical of these highly specialized alloys is a binary alloy containing 2 per cent manganese which has high resistance to slightly acid solutions and has excellent ductility. It has limited use because of its difficult casting characteristics.

Controlled electrical conductivity is required in some electrical equipment. When maximum conductivity is required, controlled compositions of essentially pure aluminum are used. Where the design permits slightly lower conductivity, the addition of 1.5 per cent silicon materially improves the casting qualities. Where low electrical conductivity is necessary, an alloy containing 6 per cent magnesium, 1.5 per cent manganese, and 1.5 per cent nickel can be used.

These special alloys have their place and should be specified when needed, but only when needed. The buyer will obtain castings of lowest cost by keeping his specifications as simple as possible. In other words, a heat-treated alloy should not be specified if a nonheat-treated one will do. An alloy having difficult casting characteristics should not be selected if one easier for the foundryman to handle will serve.

Informational booklets are published by practically all of the producers of aluminum alloys, and these may be consulted for further details on any specific alloy.

Soliciting Bids

After the casting process and alloy have been tentatively chosen, bids should be requested from a number of foundries. At least three should be chosen so that the buyer will have reasonable assurance that the foundry

finally selected to do the job will be representative.

The most important consideration in selecting bidders is the foundries' reputations as to consistency of quality and service. Foundries having considerable experience in producing the type of casting under consideration should be chosen. It is equally important to be sure that these foundries have the facilities to produce the castings at the required production rate.

Each bidder should be given a detailed dimensional drawing of the part and full information on service conditions. Both the total quantity and required rate of delivery must be specified, for these are important factors in determining costs.

In preparing drawings, all surfaces to be machined should be clearly indicated, as well as permissible dimensional tolerances. Close tolerances should be specified only where necessary. Dimensional tolerances can be held much closer in permanent mold than in sand castings, while in die castings still closer tolerances are possible.

If a model or test pattern of the part is available, it should be submitted to all bidders. When a reorder is under consideration, a sample casting as previously made should be sent.

Except where a pattern, mold, or die is already available, the buyer should be sure that bidders have adequate facilities for designing and producing such equipment. This is especially important if the part is to be made by either the permanent-mold or die-casting process. In any event, allowances must be made for shrinkage of the metal as it solidifies, for adequate draft so that either the pattern or the casting may be easily removed from the mold (depending upon which process is used), and for finishing where machined surfaces are required. In the interest of accuracy, the main machining locating points should be specified before the pattern, mold, or die design is determined.

Service conditions must be specified in detail in order that the foundryman may bid accurately on the production of castings that will meet those conditions. Any points of high stress should be specified, as well as pressure tightness, if that is required. If the castings are to be used where corrosive influences are present, these conditions should be clearly and fully described. If temperatures at which the castings will function differ materially from ordinary room temperature, these must be clearly indicated. Aluminum alloys are stronger at low temperatures than at room temperatures, but they lose some of their strength at elevated temperatures. If any of the casting surfaces are subject to wear, these should be clearly indicated.

Some Questions to Ask

Buyers should ask prospective suppliers a number of significant questions about their facilities. Specifically, they should ask the foundries if they have accurate temperature-control equipment for proper handling of the metal. They should also ask if the foundries

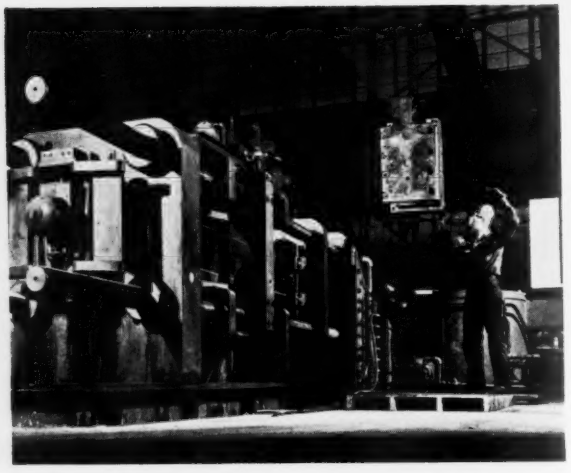
Pouring molten aluminum alloy into a permanent mold.

have inspection procedures and laboratory facilities to assure attainment of specified properties in the finished castings.

If the casting to be produced requires a high-strength alloy, the buyer should also satisfy himself as to the foundries' ability to perform heat-treatment. Attainment of maximum strength in heat-treated castings requires that temperatures in the heat-treating furnaces be held within close limits for specified lengths of time. Facilities for rapid quenching also are necessary.

One of the most important matters upon which the buyer should satisfy himself is whether the prospective supplier has a quality-control setup adequate to assure

Typical aluminum-alloy permanent-mold castings.

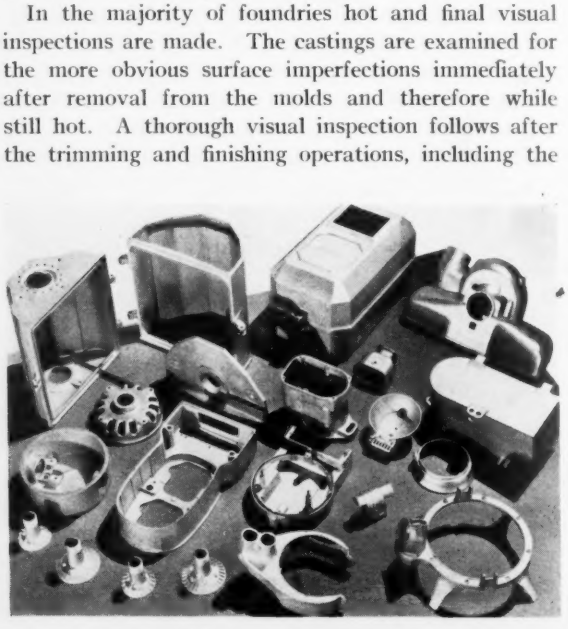


Setting a large die on a die-casting machine.

the production of good castings meeting the specifications consistently. Consideration of some of the requirements of a good quality-control procedure may help the buyer to determine this point.

An appropriate quality-control program for a given casting will depend partly on the requirements the casting must meet. For example, some highly stressed castings, such as those used for vital parts of aircraft, must receive 100 per cent X-ray inspection. Castings that are moderately stressed, where failure would not involve loss of life or serious interruption of work, would not require 100 per cent X-ray inspection but would be produced under X-ray control. The more normal commercial castings, which are under low stress and in nonstructural applications, however, require no X-ray control. A large majority of these castings are entirely satisfactory for their purposes if they meet reasonable visual inspection standards.

In the majority of foundries hot and final visual inspections are made. The castings are examined for the more obvious surface imperfections immediately after removal from the molds and therefore while still hot. A thorough visual inspection follows after the trimming and finishing operations, including the required dimensional checks. On large production runs the dimensional inspection often is facilitated by the use of a fixture or jig of the "go-no-go" type.



Typical aluminum-alloy die castings.

For castings that must be leakproof or pressure tight, a pressure test is necessary. This is made by sealing off the internal cavities or passages in a special jig and then introducing compressed air into the interior. After air pressure has been built up, pressure tightness is determined by either immersing the whole assembly into a tank of water or by applying a water-soap solution to the exterior. In either case, any leak will be indicated by bubbles appearing on the surface of the casting.

Some foundries are equipped for "chalk" or ultraviolet testing. The castings are first submerged in a bath of penetrant oil. After removal from this bath, the excess oil is cleaned from the surface of the casting. When the casting is thoroughly dry, chalk is dusted over its surface. Any oil remaining in cracks or voids which are open to the surface will darken the chalk in the areas where such imperfections exist.

The ultraviolet method is similar except that the penetrant oil contains a fluorescent dye, and the castings, after having been coated with chalk, are examined under ultraviolet radiation or "black light." Fluorescence of the oil brought to the surface by the chalk clearly indicates the location and nature of any surface discontinuities. These methods are rarely applied 100 per cent to castings in production. However, they are sometimes valuable in the development of proper foundry procedures for the production of certain types of castings.

Foundries with good quality-control setups will usually be equipped to perform all these checks or at least will have facilities at their command for performing them when necessary. A well-equipped foundry with adequate quality control also will have laboratory facilities for making both chemical and mechanical tests. Finally, a good quality-control program will be set up so that any production defects that crop up will be quickly remedied.

Where possible, the buyer should investigate the experience of other customers with prospective suppliers. As in practically all other businesses, satisfied customers are a supplier's best recommendation. This is particularly true in the aluminum-casting field where the difference between a satisfactory product and an unsatisfactory one depends so largely on experience and on good production equipment.

After a foundry has been tentatively selected, the buyer should ask to inspect the plant so that he can see for himself the equipment that would produce his castings and the conditions under which they would be made. Few reputable foundrymen will deny a prospective purchaser this privilege, and where it is denied the buyer should be especially cautious.

An important point to observe in visiting a prospective supplier is the general housekeeping in the plant. If the plant looks clean, neat, and orderly (at least to the

(*Concluded on page 55*)

A Proposed Revision of American Standard Letter Symbols for Aeronautical Sciences

by R. C. Hopgood

WITH THIS ARTICLE, the aeronautical industry and profession are invited to comment upon and to criticize the present informal (and therefore unofficial) publication of the current proposal for a revised American Standard, *Letter Symbols for Aeronautical Sciences*. In responding to this invitation, the writer would appreciate having all comments addressed to him at his office, Room 1811, 420 Lexington Avenue, New York 17, N.Y., prior to February 28, 1953. Alternatively, for those who will be attending the annual New York meeting of the Institute of the Aeronautical Sciences, a cordial invitation is extended to anyone interested to participate in the meeting of A.S.A. Subcommittee Y10.7 beginning at 2:00 p.m., Thursday, January 29, in one of the parlors (to be designated later) in the Hotel Astor, headquarters for the I.A.S. Twenty-First Annual Meeting.

Although publication of American Standard, *Letter Symbols for Aeronautical Sciences*, ASA Z10.7-1950, was followed by general approval and acceptance, the resulting comment soon brought certain deficiencies into focus. Thus, ever since the 1950 publication, work has been directed toward revision of the Standard. It was at first thought that a short supplement might serve the purpose of bringing the Standard up to date. However, the working subcommittee found it necessary to undertake such extensive revisions that publication of a completely revised Standard was indicated. The proposed revised Standard, as published herewith, represents a final draft, but several subcommittee members have taken the position that an opportunity for industry-wide comment would improve the value of the proposed revision. Therefore, subcommittee activities are being suspended until the profession has offered its views, within the above-indicated period for comment.

Background.—Preparation of the Standard and of the present revision has been the responsibility of Subcommittee No. 7 on Aeronautical Sciences, one of 15 subcommittees appointed by Sectional Committee Y10 on Letter Symbols. The other subcommittees cover mathematics, hydraulics, mechanics of solid bodies, structural analysis, heat and thermodynamics, photometry, electrical and magnetic quantities, radio, physics, chemical engineering, acoustics, meteorology, feedback-control systems, and abbreviations.

Sectional Committee Y10 was organized under the procedure of the American Standards Association in January, 1926, with the American Society of Civil Engineers, the American Institute of Electrical Engineers, the American Society for Engineering Education, The American Society of Mechanical Engineers, and the American Association for the Advancement of Science as joint sponsors. The committee was reorganized in October, 1935, and it now consists of representatives of 42 national societies and associations; under the reorganization of April, 1951, The American Society of Mechanical Engineers has assumed the role of sole sponsor.

Subcommittee No. 7 was originally constituted in April, 1926, and submitted a proposal that was issued as a Standard in 1930. Rapid developments in concepts relating to the aeronautical sciences rendered the 1930 Standard obsolete, and the subcommittee was reconstituted in June, 1947, with substantially its present membership, for the purpose of developing a new Standard. A proposed Standard was published in January, 1949, for trial and criticism (AERONAUTICAL ENGINEERING REVIEW, June, 1949, page 8), and the resulting American Standard was published in January, 1950 (AERONAUTICAL ENGINEERING REVIEW, June, 1950, page 28). In order to develop a broad base for acceptance of the current proposal, every effort has been made to have the subcommittee membership reflect wide representation from industry, academic institutions, and the Government (see Personnel for Subcommittee 7). Also, the subcommittee has been particularly fortunate in having the Institute of the Aeronautical Sciences, the National Advisory Committee for Aeronautics, and, more recently, the American Rocket Society participate as collaborators in drafting the present revision.

Soon after the 1950 publication of American Standard Z10.7, major controversies and deficiencies developed in three principal fields, and the subcommittee appointed special subgroups to resolve these controversies and deficiencies. All three subgroups presented final reports at 1952 meetings, and the principal remaining controversy is discussed at greater length below. Subgroup No. 1 was concerned with a thorough overhauling of subcommittee recommendations with regard to axis systems and designations and was under the chairmanship of Dr. H. K. Skramstad, of the National Bureau of Standards. Subgroup No. 2 was charged with responsibility for recommending less cumbersome number designations and was under the chairmanship of Dr. J. A. Hootman, of the N.A.C.A. Subgroup No. 3, under I. E. Garrick, also of the N.A.C.A., had the responsibility for recommending additional concepts and symbols having particular application to flutter problems.

The Proposed Revision.—The proposed revision will generally resemble the 1950 version of the Standard. As planned, the Standard proper will be wholly con-

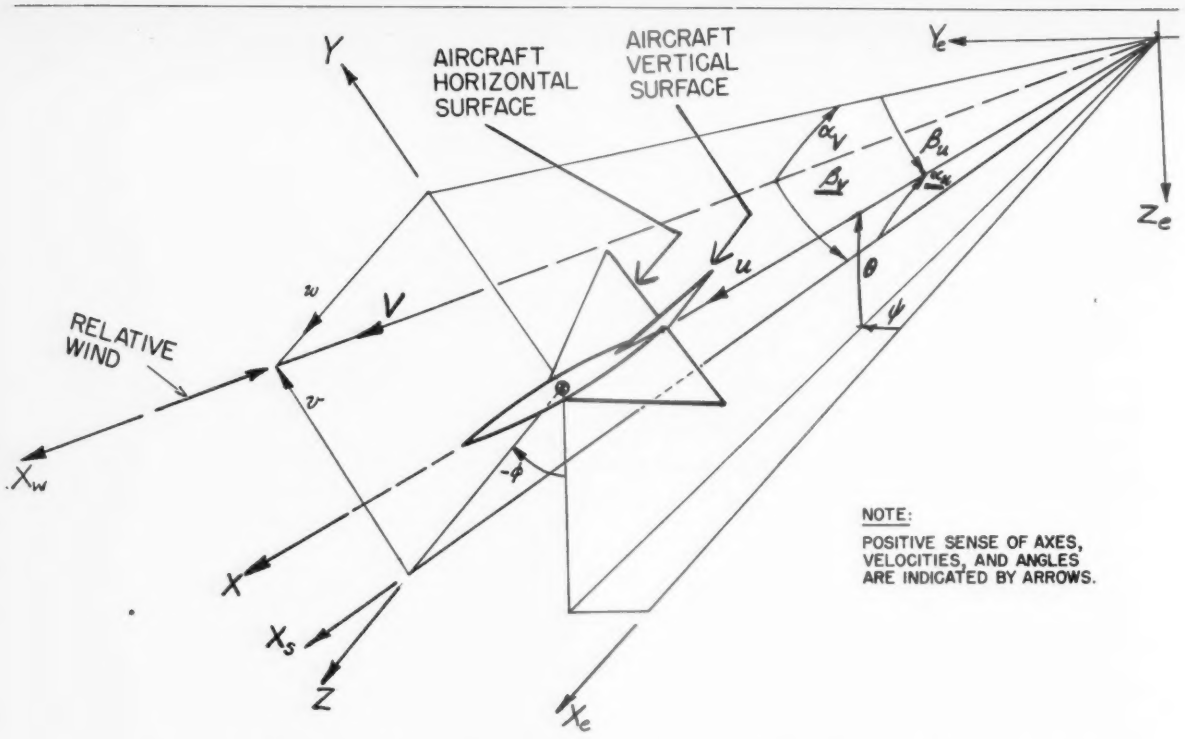


Figure 1.- Orientation of coordinate systems, showing direction and sense of Euler angles.

tained within a first section, which is the only portion reproduced in the present publication. This section comprises two listings alphabetically by symbol, first for primary concepts and then for secondary concepts. In order to supplement this listing, there is to be a first appendix providing an alphabetical index by concept, followed by a second appendix describing at length recommended designations for axis systems, angular relationships, and quantities related thereto.

In the presently published excerpt from the proposed Standard, the first two columns—namely, the symbol column and the concept column—constitute the proposed revised American Standard, and all other columns and listings are merely to facilitate use of the Standard. In the third column, illustrative dimensions are given, but these dimensions are not a part of the standard. In the fourth column, the extent of agreement with other current American Standards is indicated, and it will be noted that this agreement remains substantial. In the fifth column are certain remarks, including definitions, but these also form no part of the Standard.

The proposed Standard incorporates several new concepts, some of which were inadvertently omitted from the 1950 version. Many of the new concepts pertain to flutter problems and to axis designations, and the symbols for angular rates, so long identified with usage, have now been brought into the standard. The subject of recommended axis designations is, as indicated above, treated at length in Appendix II, which is not reproduced with the present publication but which includes two new illustrations reproduced herewith (Figs. 1 and 2, of which Fig. 1 is still controversial, see below). See page 50 for Fig. 2.

In general, any of the recommended letter symbols for primary concepts may be employed as subscripts in application to another symbol for a primary concept. This recognizes the fact that a given primary concept may, under certain circumstances, be employed as a modifying or secondary concept. For this reason, there has been no deliberate attempt made to include in the subscript list all of the symbols that may be employed as subscripts, particularly where such symbols may be found in the published listing of principal letter symbols.

In designating aircraft components, it is recommended that lower-case letters be generally used whenever the terms occur in mathematical expressions—e.g., b_e = *elevator span;* S_w = *wing area.* Capital letters should be used to designate component parts of a configuration, as used in models for wind-tunnel testing, and various components of the model under test should be distinguished by means of numerical subscripts; thus $F_1W_3N_2$ would represent a model including the No. 1 fuselage, the No. 3 wing, and the No. 2 nacelle. Since the configuration symbols are not usually employed as subscripts, they are not included in the present list of subscripts; thus, in the present list of subscripts, symbols for aircraft components appear as lower-case letters.

Principal Controversies.—With a view to soliciting professional comment, the subcommittee is anxious to present herewith a brief review of the outstanding con-

(*Continued on page 50*)

AMERICAN STANDARD

Letter Symbols for Aeronautical Sciences

A symbol indicated as an alternate is not preferred. Symbols having equal rank are not qualified as alternates.

The dimensions given in the third column and the definitions given in the fifth column are merely illustrative and form no part of the present standard. With regard to the indicated dimensions, and in a particular system of units, M represents Mass, L represents Length, T represents Time, and θ represents Temperature.

Letter Symbols for Primary Concepts

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
a (lc)	Slope of lift curve	Dimensionless	———	$a = \frac{dC_L}{d\alpha}$
a (lc)	Velocity of sound	LT^{-1}	———	Use c (lc) for alternate
A (cap)	Area, cross-sectional	L^2	Z10.2,Z10.4,Z10.6, Z10.8,Z10.12	Use S (cap) for surface or projected area
A (cap)	Aspect ratio	Dimensionless	———	See $\mathfrak{AR}$ (cap, written together) for alternate
$\mathfrak{AR}$ (cap, written together)	Aspect ratio, alternate for	Dimensionless	———	———
b (lc)	Blade width (propellers)	L	———	———
b (lc)	Semichord, alternate for $c/2$ (flutter)	L	———	———
b (lc)	Span	L	Used in Z10.3,Z10.6, Z10.8 for breadth	Use s (lc) for alternate for semispan ($b/2$)
c (lc)	Chord, of an airfoil	L	———	Use b (lc) as alternate for $c/2$, semichord (flutter)
c (lc)	Section coefficient	Dimensionless	———	———
c (lc)	Section coefficient (flutter)	Dimensionless	———	In flutter, section coefficients reduce to steady-flow coefficients under steady flow conditions. Use subscripts or superscripts to indicate any or all of the following items: (1) Whether for lift or moment, (2) Acting on what component or about what axis, (3) Due to what kind of motion (or degree of freedom) (4) Of what component. These items may be indicated in the form c_{12}^{34} (e.g. c_{la}^{hv}); since c_{12}^{34} is, in general, a complex quantity, it can be divided into its real and imaginary parts, as:– $c_{12}^{34} = \left(c_{12}^{34}\right)_r + i\left(c_{12}^{34}\right)_i$

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
c (lc)	Velocity of sound, alternate for; gas velocity (rockets)	LT^{-1}	Z10.6,Z10.12	
c_p (lc)	Specific heat, at constant pressure	$L^2T^{-2}\theta^{-1}$	Z10.4,Z10.6,Z10.12	
c_v (lc)	Specific heat, at constant volume	$L^2T^{-2}\theta^{-1}$	Z10.4,Z10.6,Z10.12	
C (cap)	Circulation function, for harmonic oscillations (flutter)	Dimensionless		Used in expressing a function, as $C(k)$, meaning circulation function of reduced frequency k (see NACA Report 496 by Theodorsen). $C(k) = F(k) + iG(k)$, or, in terms of Hankel functions, $C(k) = \frac{H_1^{(2)}}{H_1^{(2)} + iH_0^{(2)}}$
C (cap)	Coefficient	Dimensionless	Z10.2	See Appendix II; also see K (cap) for factor which may have dimensions
C (cap)	Concentration	Dimensionless	Z10.4	
C (cap)	Cross-wind force	MLT^{-2}		See Appendix II
d (lc)	Diameter	L	Z10.3,Z10.4	Interchangeable, but conflicts with differential operators shall be avoided
D (cap)	Diameter	L	Z10,2,Z10.3,Z10.4, Z10.6,Z10.8,Z10.12	
D (cap)	Drag	MLT^{-2}		
e (lc)	Span effectiveness	Dimensionless		
e (lc)	Internal energy, per unit mass or per unit weight	L^2T^{-2} (per unit mass); L (per unit weight)		Use where conflict is to be avoided
E (cap)	Energy	ML^2T^{-2}	Z10.2,Z10.3,Z10.6, Z10.8,Z10.12	
E (cap)	Modulus of elasticity; Young's modulus	$ML^{-1}T^{-2}$	Z10.3,Z10.6,Z10.8	
f (lc)	Cyclic frequency	T^{-1}	Z10.3,Z10.6,Z10.8	Distinguish from ω (lc) for circular frequency
F (cap)	Force; resultant force	MLT^{-2}	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	See Appendix II
F (cap)	Thrust; stream thrust (combustion)	MLT^{-2}		Use T (cap) for propeller thrust
g (lc)	Acceleration due to gravity	LT^{-2}	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	
g (lc)	Structural damping coefficient (flutter)	Dimensionless		Use with appropriate subscript to indicate type of vibration. Section damping force or moment may be introduced proportional to amplitude and in phase with velocity, as, for example, by applying the factor $(1+ig)$ to the stiffness term

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
G (cap)	Mass velocity; mass-flow, per unit cross-sectional area, per unit time; weight-flow, per unit cross-sectional area, per unit time.	$ML^{-2}T^{-1}$ (mass flow) $ML^{-1}T^{-3}$ (weight-flow)	Z10.4,Z10.12	
G (cap)	Shear modulus	$ML^{-1}T^{-2}$	Z10.8	
h (lc)	Altitude	L	Z10.6,Z10.8	
h (lc)	Blade thickness (propellers)	L	Z10.3	
h (lc)	Deflection, from a specified plane, due to bending (flutter)	L		Function of space coordinates and time; use z (lc) for alternate, when with reference to x-y plane
h (lc)	Enthalpy, per unit mass or per unit weight: specific enthalpy	L^2T^{-2} (per unit mass) L (per unit weight)	Z10.4,Z10.6,Z10.12	
h (lc)	Heat-flow rate, per unit of area, per degree, across a boundary surface	$MT^{-3}\theta^{-1}$	Z10.4	Discourage use of the term film coefficient
H (cap)	Angular momentum	ML^2T^{-1}		
H (cap)	Enthalpy; total heat content	ML^2T^{-2}	Z10.4,Z10.6,Z10.12	
i (lc)	Angle of incidence	Dimensionless		Usually characterized by a subscript
I (cap)	Impulse	MLT^{-1}		Subscripts must always be used to connote type of impulse
I (cap)	Mass moment of inertia	ML^2	Z10.3,Z10.6,Z10.8,Z10.12	
I (cap)	Mass moment of inertia, per unit length	ML		
I (cap)	Area moment of inertia	L^4		
J (cap)	Advance ratio of propeller	Dimensionless		
J (cap)	Mechanical equivalent of heat; Joule's constant	Dimensionless	Z10.4,Z10.6,Z10.12	Numerical value is a function of mechanical and thermal units used
J (cap)	Torsional stiffness constant	L^4		Used in torsional stiffness GJ; same as area polar moment of inertia only for a circular cross-section
k (lc)	Radius of gyration	L	Z10.6,Z10.8	
k (lc)	Ratio of specific heats, alternate for	Dimensionless	Z10.4	
k (lc)	Reduced frequency (flutter)	Dimensionless		$k = \frac{\omega c}{2V} = \frac{\omega b}{V}$
k (lc)	Thermal conductivity	$MLT^{-3}\theta^{-1}$	Z10.4,Z10.6,Z10.12	
K (cap)	Factor, for comparison purposes	May have dimensions		
l (lc)	Length; distance	L	Z10.3,Z10.4,Z10.6	
L (cap)	Lift	MLT^{-2}		
L (cap)	Lift, per unit length; section lift	MT^{-2}		

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
L (cap)	Turbulence scale; correlation length (turbulence)	L		
m (lc)	Mass	M	Z10.2,Z10.3,Z10.4, Z10.6,Z10.12	
m (lc)	Mass, per unit length	ML^{-1}		
M (cap)	Mach number	Dimensionless		Use N_{Ma} for alternate
M (cap)	Moment	ML^2T^{-2}	Z10.3,Z10.8	See Appendix II
M (cap)	Moment, per unit length; section moment	MLT^{-2}		
n (lc)	Exponent of polytropic expansion	Dimensionless	Z10.4	
n (lc)	Load factor	Dimensionless		
n (lc)	Revolutions per unit time	T^{-1}	Z10.2,Z10.6,Z10.12	
N (cap)	Normal force	MLT^{-2}		
N (cap)	Number, in general	Dimensionless	Z10.2,Z10.3,Z10.4,Z10.12	Usually characterized by subscript; see Appendix I
p (lc)	Angular velocity of body-axis system about X-axis	T^{-1}		See Appendix II; use ω_X for alternate
p (lc)	Pressure; static pressure	$ML^{-1}T^{-2}$	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	
P (cap)	Power	ML^2T^{-3}	Z10.2,Z10.3,Z10.6,Z10.12	
q (lc)	Angular velocity of body-axis system about Y-axis	T^{-1}		See Appendix II; use ω_Y for alternate
q (lc)	Dynamic pressure	$ML^{-1}T^{-2}$		$1/2\,\rho V^2$
q (lc)	Quantity of heat, per unit time	ML^2T^{-3}	Z10.4	
q (lc)	Quantity of heat, per unit mass or per unit weight; specific quantity of heat	L^2T^{-2} (per unit mass) / L (per unit weight)	Z10.4,Z10.12	
Q (cap)	Quantity of heat	ML^2T^{-2}	Z10.4,Z10.6,Z10.12	
Q (cap)	Torque (propellers and rotary-wing aircraft)	ML^2T^{-2}		
r (lc)	Angular velocity of body-axis system about Z-axis	T^{-1}		See Appendix II; use ω_Z for alternate
r (lc)	Radius	L	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	
r (lc)	Reduced radius of gyration (flutter)	Dimensionless		Always used with appropriate subscript
R (cap)	Correlation coefficient (turbulence)	Dimensionless		Identification is to be made by suitable subscripts, superscripts, or indication of functional dependence
R (cap)	Gas constant	$ML^2T^{-2}\theta^{-1}$	Z10.4,Z10.6,Z10.12	
R (cap)	Range	L		

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
R (cap)	Reynolds number	Dimensionless	Z10.2,Z10.4	See Appendix I
R (cap)	Richness; equivalence ratio (combustion)	Dimensionless	———	Richness is >1 on the rich side of the stoichiometric mixture, and <1 on the lean side; use R_f meaning richness of the fuel, when necessary to distinguish from other concepts connoted by R
s (lc)	Entropy, per unit mass or per unit weight; specific entropy	$L^2T^{-2}\theta^{-1}$ (per unit mass) $L\theta^{-1}$ (per unit weight)	Z10.4,Z10.6,Z10.12	———
s (lc)	Semispan, alternate for	L	———	Alternate for $b/2$
S (cap)	Entropy	$ML^2T^{-2}\theta^{-1}$	Z10.4,Z10.6,Z10.12	———
S (cap)	Area, surface or projected	L^2	Z10.6,Z10.12	Use A (cap) for cross-sectional area
t (lc)	Temperature, general	θ	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	Use θ (lc) for alternate
t (lc)	Thickness	L	Z10.2,Z10.4,Z10.8	———
t (lc)	Time	T	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	Use τ (lc) for alternate
T (cap)	Temperature, absolute	θ	Z10.2,Z10.3,Z10.4, Z10.6,Z10.12	———
T (cap)	Thrust (propellers and rotary-wing aircraft)	MLT^{-2}		Use F (cap) for other types of thrust
u (lc)	Internal energy, per unit mass or per unit weight; specific internal energy	L^2T^{-2} (per unit mass) L (per unit weight)	Z10.4,Z10.6,Z10.12	Use e (lc) for alternate
u (lc)	Velocity, component of, along X-axis	LT^{-1}	Z10.2,Z10.6	See Appendix II
U (cap)	Internal energy	ML^2T^{-2}	Z10.4,Z10.6,Z10.12	Use E (cap) for alternate
U (cap)	Heat transfer coefficient, over-all	$MT^{-3}\theta^{-1}$	Z10.4,Z10.12	———
U (cap)	Velocity, alternate for; gust velocity	LT^{-1}	———	———
v (lc)	Velocity, compoent of, along Y-axis	LT^{-1}	Z10.2,Z10.6	See Appendix II
v (lc)	Volume, per unit mass or per unit weight; specific volume	$M^{-1}L^3$ (per unit mass) $M^{-1}L^2T^2$ (per unit weight)	Z10.4,Z10.6,Z10.12	———
V (cap)	Velocity, resultant; speed	LT^{-1}	Z10.2,Z10.4,Z10.12	Use U (cap) for alternate; use either subscripts (*e.g.*, V_x, V_y, V_z) or u, v, w for velocity components
V (cap)	Volume	L^3	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	
w (lc)	Velocity, component of, along Z-axis	LT^{-1}	Z10.2,Z10.6	See Appendix II
w (lc)	Weight flow, per unit time; mass-flow per unit time	MLT^{-3} (weight flow) MT^{-1} (mass flow)	Z10.4,Z10.12	———
W (cap)	Weight	MLT^{-2}	Z10.2,Z10.3,Z10.4, Z10.6,Z10.8	———

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
x (lc)	Coordinate along X-axis	L		See Appendix II for designation of axes
X (cap)	Isentropic factor	Dimensionless	Z10.4	
y (lc)	Coordinate along Y-axis	L		See Appendix II
z (lc)	Coordinate along Z-axis	L		See Appendix II
z (lc)	Deflection normal to x-y plane (flutter)	L		See h (lc)
α (lc)	Angle of attack, relative to wind	Dimensionless		Defined as arctan $\frac{w}{u}$; see Appendix II
α (lc)	Angular acceleration	T^{-2}	Z10.2,Z10.3,Z10.6,Z10.8	
α (lc)	Diffusivity, thermal	L^2T^{-1}		
α (lc)	Nozzle divergence half angle	Dimensionless		
β (lc)	Angle of side slip; angle of yaw, relative to wind	Dimensionless		Defined as arcsin $\frac{-v}{V}$; See Appendix II
β (lc)	Blade angle (propellers)	Dimensionless		
β (lc)	Mach number relation	Dimensionless		$\beta = \lvert 1-M^2 \rvert^{1/2} = \lvert M^2-1 \rvert^{1/2}$
β (lc)	Nozzle convergence half angle	Dimensionless		
γ (lc)	Ratio of specific heats	Dimensionless	Z10.4,Z10.6,Z10.12	Use k (lc) for alternate
γ (lc)	Strain, shear	Dimensionless	Z10.3, Z10.8	
γ (lc)	Flight-path angle	Dimensionless		Angle between a horizontal plane and instantaneous direction of motion of body center of gravity; see Appendix II
Γ (cap)	Circulation; strength of a single vortex	L^2T^{-1}		
Γ (cap)	Dihedral angle	Dimensionless		
δ (lc)	Boundary layer thickness	L		See θ (lc) for momentum thickness of boundary layer
δ (lc)	Displacement, angular, of control surface or tab	Dimensionless		Differential deflections must be clearly defined; in flutter, symbol β (lc) is often employed for control-surface displacement
δ (lc)	Logarithmic decrement of viscous (or equivalent viscous) damping	Dimensionless		
δ (lc)	Relative pressure	Dimensionless		Ratio of a pressure to the standard pressure of atmospheric air at sea level
ϵ (lc)	Angle of downwash	Dimensionless		
ϵ (lc)	Error signal	Dimensionless		
ϵ (lc)	Strain,normal	Dimensionless	Z10.3,Z10.8	
ϵ (lc)	Turbulence exchange coefficient	$ML^{-1}T^{-1}$		
ϵ (lc)	Emissivity (for radiant heat)	Dimensionless	Z10.4,Z10.6,Z10.12	

Symbol	Concept	Dimensions	Also Appears in Z10 Publication	Remarks
η (lc)	Efficiency	Dimensionless	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	
η (lc)	Temperature-recovery factor	Dimensionless		
θ (lc)	Angle of pitch	Dimensionless		See Appendix II
θ (lc)	Angle of twist of an elastic component	Dimensionless		Symbol α is often employed as an alternate in flutter
θ (lc)	Momentum thickness of boundary layer	L		
θ (lc)	Temperature, alternate for	θ	Z10.4,Z10.6	Use t (lc) if possible
θ (lc)	Temperature ratio	Dimensionless		Ratio of an absolute temperature to the standard absolute temperature for atmospheric air at sea level
λ (lc)	Mean free path	L		
λ (lc)	Microscale (turbulence)	L		Associated with turbulence decay
λ (lc)	Nozzle divergence factor	Dimensionless	Z10.6	The theoretical ratio of thrust of a diverging nozzle to the thrust without divergence of the flow
λ (lc)	Taper ratio	Dimensionless		In any given tapered wing element, the ratio of chord at the tip end to chord at the root end
λ (lc)	Wave length	L	Z10.3,Z10.4,Z10.6	
Λ (cap)	Sweepback angle	Dimensionless		
μ (lc)	Mach angle	Dimensionless		$\mu = \sin^{-1}\frac{1}{M} = \tan^{-1}\frac{1}{\beta}$
μ (lc)	Mass parameter of airplane component (flutter)	Dimensionless		$\mu = \frac{4m}{\pi\rho c^2}$; symbol $\frac{1}{\kappa}$ has been used as an alternate
μ (lc)	Viscosity absolute; viscosity, coefficient of	$ML^{-1}T^{-1}$	Z10.2,Z10.4,Z10.12	
μ (lc)	Poisson's ratio	Dimensionless	Z10.3	
ν (lc)	Kinematic viscosity	L^2T^{-1}	Z10.2,Z10.4,Z10.6,Z10.12	$\nu = \frac{\mu}{\rho}$
ρ (lc)	Mass density	ML^{-3}	Z10.2,Z10.3,Z10.4,Z10.6, Z10.8,Z10.12	Such that $1/2\rho V^2$ = pressure
σ (lc)	Angle of sidewash	Dimensionless		
σ (lc)	Relative density	Dimensionless		Ratio of a density to the standard density of atmospheric air at sea level
σ (lc)	Solidity (propellers)	Dimensionless		
σ (lc)	Stress, normal; stress (intensity)	$ML^{-1}T^{-2}$	Z10.2,Z10.3	
τ (lc)	Stress, shearing	$ML^{-1}T^{-2}$	Z10.2,Z10.3	
τ (lc)	Time, alternate for	T	Z10.4,Z10.6,Z10.12	Use t (lc) if possible
τ (lc)	Time ratio	Dimensionless		

Symbol	Concept	Dimensions	in Z10 Publication	Remarks
ϕ (lc)	Angle of roll (or bank)	Dimensionless	———	See Appendix II
ϕ (lc)	Potential function	Dependent on definition	———	———
ϕ (lc)	Helical angle of advance (propellers)	Dimensionless	———	———
ψ (lc)	Angle of yaw; effective helix angle	Dimensionless	———	See Appendix II
ψ (lc)	Stream function	Dependent on definition	———	———
ω (lc)	Angular velocity; circular frequency	T^{-1}	Z10.2,Z10.3,Z10.4,Z10.6 Z10.8,Z10.12	Use Ω (cap) as alternate for angular velocity
Ω (lc)	Angular velocity, alternate for; vorticity	T^{-1}	———	If possible, use ω (lc) for angular velocity

(*Continued from page 42*)

troversies that it is hoped will be resolved prior to acceptance of the proposed revision.

The first controversy concerns the problem of double-letter symbols, such as *Pr* as a symbol for the primary concept of Prandtl Number. In the 1950 version of the Standard, the subcommittee was mindful of the A.S.A. prohibition against double-letter symbols for primary concepts, and, therefore, the subcommittee could make no recommendation other than that the double-letter designations should be employed only as subscripts to the principal letter symbol *N* (Number, in general). Recommendations of the 1950 Standard were the subject of extensive criticism on this point; hence, the formation of Subgroup No. 2 mentioned above. After much discussion at several meetings, the subcommittee saw no clear way out of the dilemma created by the current extensive usage of the double-letter symbols for these special primary concepts. However, it

(*Continued on page 54*)

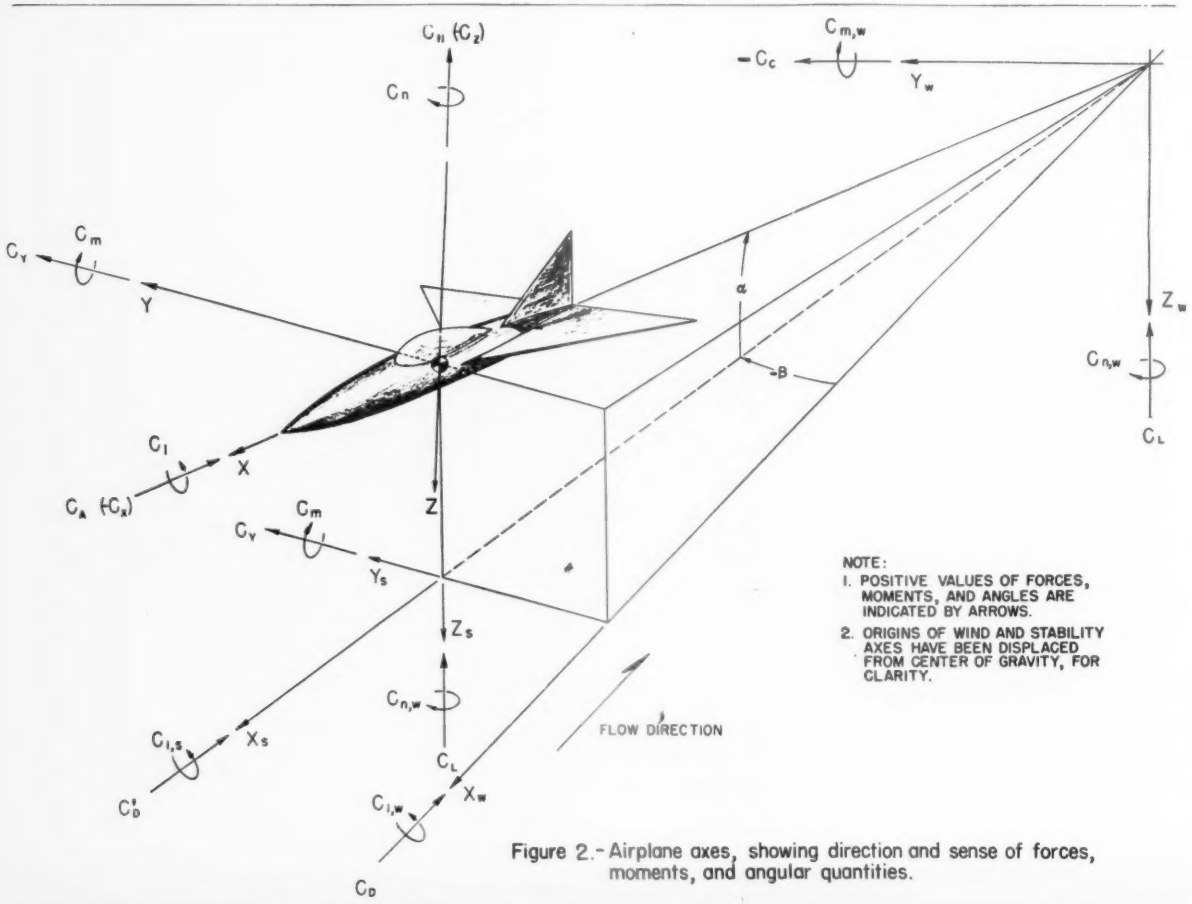


Figure 2.- Airplane axes, showing direction and sense of forces, moments, and angular quantities.

Letter Symbols for Secondary Concepts

SYMBOLS FOR USE AS SUBSCRIPTS

(Note: Letter symbols for primary concepts may also be used for subscripts; see FOREWORD)

Subscript Symbols	Concept	Remarks
a (lc)	Absolute	———
	Added; additional	———
	Adiabatic	See also *ad* (lc) for alternate; use *aw* (lc) for adiabatic wall
	Aileron	———
	Air; relative to air	———
	Allowable	———
	Ambient	See *am* (lc) for alternate
	Available	———
ac (lc)	Aerodynamic center (of a surface or airfoil section)	———
ad (lc)	Adiabatic, alternate for	———
am (lc)	Ambient, alternate for	———
av (lc)	Average	See also *m* (lc) for mean
b (lc)	Base	———
	Basic	———
	Bending	See *h* (lc) for alternate
	Blade	———
	Burner; burnt; burning	———
bar (lc)	Barometric	———
B (cap)	Body	See also *f* (lc) for fuselage
c (lc)	Calibrated	Use *cal* (lc) for alternate
	Chord	———
	Climb	———
	Combustion; combustion chamber	Use *b* (lc) for combustion chamber in gas-turbine powerplants to distinguish from *c* (lc) for compressor
	Compressibility, compressible, compression, compressor	———
	Coolant	Use *cl* (lc) for alternate
	Critical	Use *cr* (lc) for alternate
cal (lc)	Calibrated, alternate for	———
calc (lc)	Calculated	———
cg (lc)	Center of gravity	———
cl (lc)	Coolant, alternate for	———
corr (lc)	Corrected	———
cp (lc)	Center of pressure	———
cr (lc)	Critical, alternate for	———
C (cap)	Cross-wind	Perpendicular to plane of lift and drag
Ca	Cauchy (number)	———
d (lc)	Damping, general	Replace by symbol indicating axis or angular velocity, when possible
	Diffuser; duct	———
	Discharge	Use only for the discharge coefficients of nozzles and orifices
	Dry	———
D (cap)	Drag	Use *d* (lc) for section coefficient
e (lc)	Earthbound	As applied to axes or to vector components; see Appendix II
	Effective	Use *eff* (lc) as alternate
	Elevator	———
	Endurance	———
	Engine	———
	Equivalent	———
	Exhaust; exhaust nozzle; exit	———
eff (lc)	Effective, alternate for	———
Eu	Euler (number)	———
f (lc)	Fin	———
	Flap; flipper	———
	Fluid; liquid phase	See *l* (lc) for alternate
	Flutter	———
	Friction; friction factor	———
	Fuel	———
	Fuselage; body	See also *B* (cap) for body
F (cap)	Force; thrust	See also *T* (cap) for thrust
	Frontal	———
Fr	Froude (number)	———
g (lc)	Gage	———
	Gas; combustion gases; exhaust gas	———

Subscript Symbols	Concept	Remarks
g (lc)	Gross	May require care in definition
Gr	Grashof (number)	———
Gz	Graetz (number)	———
h (lc)	Bending, alternate for	———
	Heat; heat exchanger	———
	Hinge	———
	Horizontal	———
	Hub	See also *r* (lc) for root
H (cap)	Higher	Used primarily as applied to heat of combustion
i (lc)	Ideal	———
	Incidence (angle)	———
	Indicated; observed	———
	Induced	———
	Inertial	As applied to axes or to vector components; see Appendix II
	Inlet; intake; input	———
	Inner; internal	———
	Interference	———
j (lc)	Jet	May require care in definition
k (lc)	Kinetic	———
l (lc)	Liquid phase, alternate for	If italicized symbol is not available, it is recommended that the script ell be used
	Local condition, just outside boundary layer	
	Lower (surface)	
	Rolling moment	See Appendix II
lam (lc)	Laminar	———
lat (lc)	Lateral	———
le (lc)	Leading edge	———
L (cap)	Landing conditions	———
	Left	———
	Level	Use *l* (lc) for section coefficient
	Lift	Use primarily as applied to heat of combustion
	Lower	
m (lc)	Mean	See also *av* (lc) for average
	Pitching moment	See Appendix II
max (lc)	Maximum	———
min (lc)	Minimum	———
M (cap)	Moment, in general	———

Subscript Symbols	Concept	Remarks
Ma	Mach (number)	When used as a subscript this double-letter form is recommended for consistency with designations for other dimensionless numbers
n (lc)	Net	May require care in definition
	Normal to a surface	———
	Nozzle	———
	Yawing moment	See Appendix II
np (lc)	Neutral point (of a configuration	———
N (cap)	Normal (perpendicular to longitudinal axis); normal (force)	———
Nu	Nusselt (number)	———
o (lc)	Initial	———
	Outer	———
	Oxidizer	See *ox* (lc) for alternate
	Profile (drag)	———
	Standard or reference condition; standard sea-level conditions	See superscript asterisk (*) for characteristic or reference value; see *sl* (lc) for alternate for sea-level conditions
	Zero lift	———
ox (lc)	Oxidizer, alternate for	———
p (lc)	Parasite; parasitic	See *para* (lc) for alternate
	Polar	———
	Potential	———
	Pressure, based on	———
	Propellant; propeller; propulsive; tailpipe	———
para (lc)	Parasite, alternate for	———
P (cap)	Power	———
Pe	Peclet (number)	———
Pr	Prandtl (number)	———
Q (cap)	Torque (propellers and rotary-wing aircraft)	See also *M* (cap) for moment
r (lc)	Radial	———
	Ram	May require care in definition

Subscript Symbols	Concept	Remarks
r (lc)	Recovery	———
	Reference condition, alternate for	———
	Relative	———
	Root	———
	Rotor; rotational	See *R* (cap) for alternate
	Rudder	———
R (cap)	Resultant	———
	Right	———
	Rotor, alternate for; rotational, alternate for	———
Re	Reynolds (number)	———
s (lc)	Shaft	———
	Shear	———
	Slipstream	———
	Speed-power	———
	Stability	As applied to axes or to vector components. See Appendix II
	Stabilizer	———
	Surface, alternate for	———
sl (lc)	Standard sea-level, alternate for	———
sp (lc)	Specific	———
st (lc)	Static	———
std (lc)	Standard, alternate for	———
S (cap)	Stall conditions	———
St	Stanton (number)	———
t (lc)	Tab	See *Tab* for alternate
	Tail	———
	Tangential	———
	Tensile	———
	Throat	See *th* (lc) for alternate
	Tip	———
	Total; isentropic stagnation conditions	See also superscript zero (°)
	Turbine	———
tab (lc)	Tab, alternate for	———
te (lc)	Trailing edge	———
th (lc)	Theoretical	———
	Throat, alternate for	———
turb (lc)	Turbulent	———
T (cap)	Take-off and terminal velocity conditions	———

Subscript Symbols	Concept	Remarks
	Thrust (for propellers and rotary-wing aircraft	See also *F* (cap) for force; thrust
	Tunnel	———
u (lc)	Ultimate	———
	Upper (surface)	———
v (lc)	Vertical	———
	Vapor	———
vol (lc)	Volumetric	———
w (lc)	Wall; surface	See *s* (lc) for alternate
	Wind	———
	Wing	———
We	Weber (number)	———
W (cap)	Wave	———
xs (lc)	Excess	———
X (cap)	Component parallel to X-axis	Positive in positive X direction; see Appendix II
y (lc)	Yield	———
Y (cap)	Component parallel to *Y*-axis	Positive in positive Y direction; see Appendix II
Z (cap)	Component parallel to *Z*-axis	Positive in positive Z direction; see Appendix II
δ (lc)	Angular deflection of a control surface or tab	———
δ (lc)	Boundary-layer thickness, based on	———
θ (lc)	Elastic angular deflection; twist	———
ρ (lc)	Density, based on	———
σ (lc)	Condition which applies immediately after shock	———
0,1,2,3,4...	Station subscripts	———
∞	Undisturbed; free-stream	———

SYMBOLS FOR USE AS SUBSCRIPTS

Superscript Symbol	Concept	Remarks
˙(Dot)	First derivative, with respect to time	These symbols are written over, not after, the principal symbol to which they are applied
¨(Double-dot	Second derivative, with respect to time	
′(Prime)	First derivative, with respect to distance; effective or precise value	Used in turbulent-flow analysis to identify a turbulent-velocity component, *e.g.*, $u' = u - \bar{u}$; also used to designate the pressure measured by a total-head tube in a supersonic stream, *e.g.*, P_t'
′(Prime)	To designate a second set of axes, or quantities related to such axes	Alternate for subscripts
″(Double prime)	Second derivative, with respect to distance	Commonly used for value per unit area
–(Bar)	Mean value	This symbol is written over, not after, the principal symbol to which it is applied
+ (Plus)	A dimensionless measure of the quantity considered	Commonly used for boundary-layer flow and for flow in pipes
^{0}(Zero)	Total; isentropic stagnation conditions	See also subscript *t* (lc)
*(Asterisk)	Characteristic or reference value; critical conditions at $M = 1$	As applied to *u* (lc) – friction velocity (u^*); as applied to δ (lc) – displacement thickness of boundary layer (δ^*)

(*Continued from page 50*)

was noted that the working subcommittee on heat and thermodynamics (ASA Y10.5) is now in the process of reactivation and that the problem of double-letter symbols, some of which pertain primarily to thermodynamics, is more properly the concern of that particular working subcommittee. Therefore, the aeronautics subcommittee has referred the matter to the thermodynamics subcommittee, leaving the previous more cumbersome recommendation substantially without change until the thermodynamics subcommittee is able to make recommendations more acceptable to the aeronautics subcommittee.

The second controversy has arisen within the membership of Subgroup No. 1 on axis designations, and it concerns principally the definitions for angles of attack and sideslip. Opinions have been divided between those who favor strict adherence to past usage and those who favor making a clean break with tradition in order to treat angles of attack and sideslip with complete parity (for particular applicability to cruciform configurations). The latter group agrees that past usage is inconsistent and that it imposes hardship on the guided-missile people, who need the convenience of a symmetrical convention when using automatic computers in which direction cosines are used to transform between coordinate systems. The specific definitions urged by these extremes of opinion are tabulated below for comparison.

TABLE 1

Symbol	Concept	Remarks
α	Angle of attack, in general	. . .
α_u	*u*-angle of attack	Defined as arctan w/u
α_V	*V*-angle of attack	Defined as arcsin w/V
β	Angle of sideslip, in general	. . .
β_u	*u*-angle of sideslip	Defined as arctan v/u
β_V	*V*-angle of sideslip	Defined as arcsin v/V

	Usage	Symmetrical
Angle of attack, α	arctan w/u	arcsin w/V
Angle of sideslip, β	arcsin v/V	arcsin v/V

It may be argued that the function of the working subcommittee is merely to recommend symbols for concepts, as distinguished from recommending definitions for the concepts. This is certainly true, but it becomes difficult to draw an arbitrary line on this basis when the usefulness of the standard is likely to be greatly enhanced by recommending a clear definition, as in the case of the significant angles of attack and sideslip. With this in mind, limited tentative agreements have been reached for a listing along lines shown in Table 1.

Proponents of the compromise shown in Table 1 argue that, in considering pitch in the presence of a cross wind, it is customary to consider the angle β_V fixed, but not in general zero, and to consider variations of the angle α_u. Since this problem is so common, it resulted in the proposal to define angle of attack as the angle here denoted as α_u, and angle of sideslip as the angle denoted here as β_V. In consideration of cruciform-fin missiles, however, it is equally important to consider a fixed angle α_V and oscillations in yaw of the angle β_u.

In order to clarify an understanding of the proposed compromise in Table 1 and to evaluate it against past usage, it will be observed that the legends applied to Fig. 1 fully illustrate the proposed compromise. The quantities identified as α for angle of attack and as β for angle of sideslip in past usage are the quantities α_u and β_V, respectively, shown with heavy underscoring in Fig. 1. The subcommittee is particularly anxious to know the reaction of the profession to the proposed compromise.

Personnel of Subcommittee No. 7 on Letter Symbols for Aeronautical Sciences

Thomas F. Ball, Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Md., CHAIRMAN.

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C. W. Chillson, President, American Rocket Society.

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Donnell W. Dutton, Director, Daniel Guggenheim School of Aeronautics, Georgia School of Technology, Atlanta, Ga.

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How to Buy Aluminum Castings

(*Concluded from page 40*)

extent the nature of the business permits), the buyer may take this as an indication that the foundryman realizes that cleanliness contributes toward the production of better castings.

Collaboration Valuable

Buying aluminum castings thus involves more than just getting several bids and ordering from the lowest bidder. Overall cost should be the criterion, and any indications of possible difficulties, such as in machining and finishing or in adjusting rejects, should be evaluated in determining actual cost of finished castings.

Finally, after a foundry has been selected, the buyer should provide for the fullest possible consultation and collaboration between his designers and the technical personnel of the foundry. This process should begin early enough so that any acceptable changes suggested by the foundry technical men may be incorporated in the final design.

Experienced foundrymen often can suggest changes that do not in any way impair the efficacy of the design or interfere with its proper functioning and yet will greatly simplify production, reduce manufacturing cost, or result in better castings. Reputable foundrymen will offer such suggestions purely in the interest of producing castings that will most economically meet the buyer's needs, and, therefore, the buyer should give such suggestions full consideration in preparing his final design.

Conclusion

Twelve Rules for Buying Aluminum Castings

(1) Carefully estimate the number required and the rate of production so that the most economical casting method can be chosen.

(2) Determine the mechanical and physical requirements of the part so that the proper alloy, which will also be suited to the casting method, can be selected.

(3) Request bids from several foundries of good reputation which have the experience and facilities to furnish castings of the type desired at the required production rates.

(4) Submit detailed drawings and a model or test pattern when available; in a reorder, submit a sample casting as previously made.

(5) Specify service conditions in detail, especially any points of high stress or pressure tightness if required. Indicate machining locating points.

(6) Ask prospective suppliers if they have control equipment, inspection procedures, and laboratory facilities to assure the attainment of specified physical and mechanical properties consistently.

(7) If the casting requires a high-strength alloy, ask prospective suppliers if they have adequate heat-treating equipment with accurate temperature control.

(8) If possible, investigate the experience of other customers with prospective suppliers.

(9) After a supplier has been tentatively selected, visit him and see for yourself whether he has the sort of plant where you would like your castings to be made.

(10) Do not give your order to the lowest bidder unless you are satisfied that he will produce good quality castings at the lowest overall cost. Sometimes difficulties with machining and finishing and in adjusting rejects will wipe out any apparent savings.

(11) After choosing a supplier, provide for the fullest possible consultation and collaboration between your design engineers and his technical personnel.

(12) Give careful consideration to any changes the foundryman suggests which might simplify production, reduce cost, or result in better castings.

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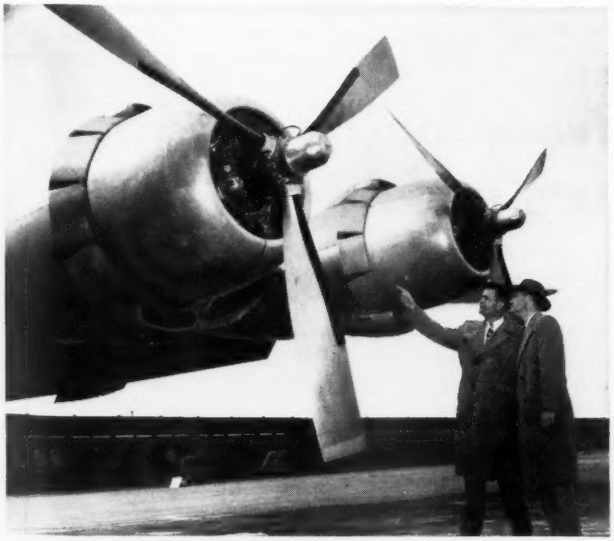

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I.A.S. Previews

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An Experimental Study of a Hypersonic Wind-Tunnel Diffuser

By

Peter P. Wegener and R. Kenneth Lobb

U.S. Naval Ordnance Laboratory, White Oak

Results of a variable-area diffuser investigation in the continuous 12- by 12-cm. Naval Ordnance Laboratory Hypersonic Tunnel No. 4 are presented. A brief introduction discusses previous supersonic diffuser work. The diffuser investigated and the experimental technique are then described. The results show that air condensation in the test section at high Mach Numbers has only a minor effect on diffuser performance. Data on overall pressure ratios for starting and maintaining hypersonic flow for a number of diffuser configurations are presented. The test Mach Numbers range from 5.9 to 9.6. From these data, a diffuser with a single-peaked throat and a three-degree plane wall divergence aft of the throat was selected as most practical. The pressure recovered by this optimum diffuser varies, depending on Mach Number, from 1.8 to 2.3 times that recovered by a pitot (or impact) tube operated at the test-section Mach Number. Data on pressure-distribution measurements throughout the nozzle and diffuser, spark schlieren photographs of diffuser flow, and data on Reynolds Number effects are also given. Finally, these data are compared with those of other investigators and with one-dimensional theory.

Reverse-Flow and Variational Theorems for Lifting Surfaces in Nonstationary Compressible Flow

By

A. H. Flax

Cornell Aeronautical Laboratory, Inc.

A reverse-flow theorem for compressible, nonsteady flow, valid within the limits of linearized theory, is derived. This theorem gives a general class of relations between linearized solutions for lifting surfaces in direct and reverse flow. Based on the same considerations as are used to establish the theorem, an adjoint variational principle, which may be useful in approximate solutions of nonsteady lifting surface problems, is obtained. To illustrate the uses of the reverse-flow theorem, it is applied to the determination of relations between aerodynamic coefficients in direct and reverse flow and to obtaining influence functions for total lift, pitching moment, and rolling moment, for a wing oscillating with arbitrary motion and surface deformation, in terms of the pressure distributions for simpler cases in reverse flow.

The Effect of the Torsional Rigidity of a Single Stiffener on the Buckling Characteristics of a Panel Subjected to Axial Compression with Large Deflections

By

T. K. Steele and C. T. Wang

Bulova Research and Development Laboratories, Inc., and New York University, Respectively

The solution of von Kármán's fundamental equations for large deflections of plates is presented for the case of a rectangular panel (2:1) with a single stiffener along its center parallel to the applied edge compressive load for the conditions where the stiffener has very low and then very high torsional rigidity relative to the plate. In both cases, the bending rigidity of the stiffener is taken of high order of magnitude compared with the plate itself and is assumed to remain unbuckled under all edge compressive loads considered.

After solving for the deflection coefficients defining the deflection patterns, it is possible to compare the critical buckling loads, effective plate widths, unit plate shortenings, membrane stresses, and bending stresses for the two cases.

On the basis of these comparisons, predictions may be made concerning the increase of permissible load-carrying capacity of panels containing rigid stiffeners against those containing nonrigid stiffeners.

Please do not order Preprints of these papers at this time.

See page 56 for Preprints that are immediately available.

Differential Shear Flow Analysis for Nonprismatic Semimonocoque Beams

By

William B. King and Walter R. Garrison

Boeing Airplane Company

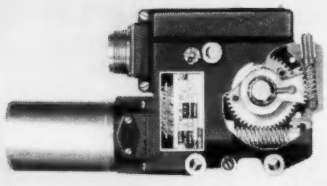
This paper gives the derivation of a method for obtaining the shear-flow distribution in a nonprismatic semimonocoque beam with nonlinear axial-load variations due to externally applied loads. This method is based on the actual rates of change of segment axial loads at a particular station rather than the average rate of change of segment axial loads between two reasonably separated stations. The particular application presented is for a wing; however, the method is applicable to any semimonocoque structure. It also has special adaptations for many loading conditions at each station.

The shear-flow distribution may be determined for each component of the loading condition such as torsion, beam, and chord shear and moment. The location of the shear center may be determined if the shear flow due to pure torsion is desired.

This method of analysis is adaptable to International Business Machine operations. The IBM calculations may be performed on machines such as the relatively slow 602 A Multiplier or the faster Card Program Sequence Calculator. The time required by IBM to calculate and check the shear-center and unit-shear flows and determine, for ten complete loading conditions, the resultant shears for a 20-segment station is approximately 30 min.

The results obtained by using the method presented in this paper on two beams, one with straight surfaces and one with curved surfaces, are compared with those obtained by VQ/I and the "Unit Method of Beam Analysis."

Jato Release on Republic's F-84 AIRBORNE Actuated



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Slender-Body Theory—Review and Extensions

By
Mac C. Adams and W. R. Sears
Cornell University

The approximate theory of flow about slender bodies and wings originated by Munk and Jones is reviewed. It is presented here in a form that emphasizes the relation to the source-sink methods of von Kármán and others. The extension to noncircular bodies is made for subsonic flow, paralleling Ward's extension for supersonic flow. The calculation of pressures and forces and the extension of the theory to unsteady flows are reviewed, and some discrepancies in the published literature are explained.

Finally, interpreting the slender-body result as the first term of an expansion in powers of a breadth parameter (e.g., aspect ratio), it is shown how a more accurate theory can be developed by carrying additional terms, for both subsonic and supersonic speeds. This theory of not-so-slender bodies and wings is applied to some practical wing problems, including direct problems of flow past given wings and problems of wing design for minimum drag. The accuracy of the new results is assessed by comparison with linearized supersonic-airfoil theory for the special case of a flat delta wing.

Preprint No. 383

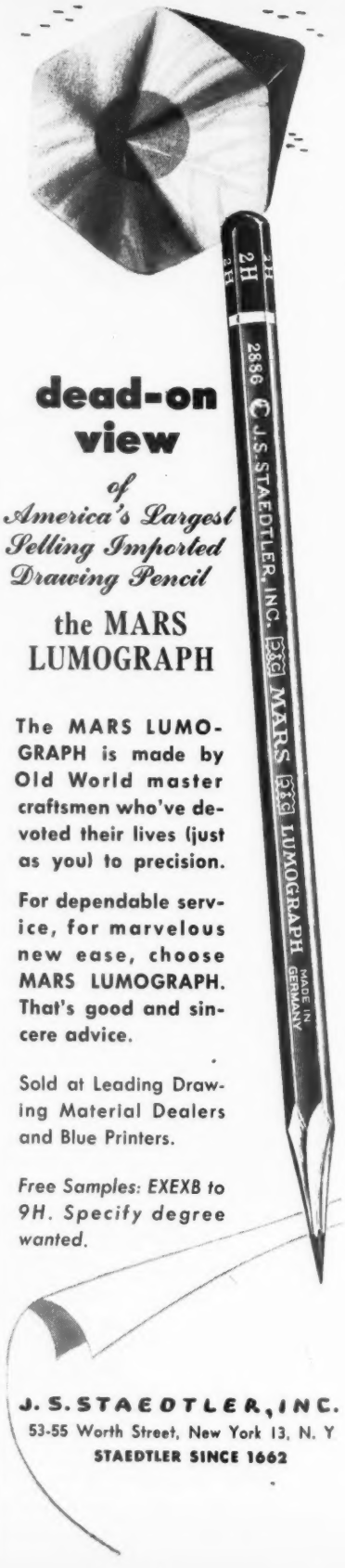
Penetration and Deflection of Jets Oblique to a General Stream

By
Fredric F. Ehrich
Westinghouse Electric Corporation

The dynamics of the entry of jets of fluid into a general stream at an oblique angle from slots and orifices is studied by means of a simplified two-dimensional potential flow analysis. The wake is approximated by an extensive area of dead fluid separated from the jet by a vortex sheet at uniform pressure. The jet is separated from the main stream by a stream line, and the jet velocity is restricted to one particular value so that there is no discontinuity across this stream line. Analysis using the conventional Helmholtz-Kirchhoff method leads to computations of the various relationships between the geometrical and velocity parameters. Calculations are also made of the shapes of jets in some common geometries.

An equivalent analysis is made of the situation in which the trailing edge of the jet does not separate from the downstream wall, and the results are compared to the analysis with separation.

The solution for the flow from a two-dimensional orifice is compared to experimental data for the roughly compa-



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rable case of flow from a circular orifice, and a qualitative agreement is shown.

The results have a possible utility in serving as a skeletal structure of a more complete analysis of the mixing process in combustion chambers and cooling films.

Generalized Theory of Convective Heat Transfer in a Free-Molecule Flow

By

A. K. Oppenheim

University of California at Berkeley

The theoretical analysis of convective heat transfer in a free-molecule flow with Maxwellian velocity distribution is generalized by reducing all relationships to a form common to all gases irrespective of their molecular structure. A simplified computing procedure is set up, and the heat transfer characteristics of a flat plate, cylinder, and sphere are presented and correlated graphically. A method of applying these results to a cone and to compound shapes is described.

On the Motion of a Tumbling Body

By

A. M. O. Smith

Douglas Aircraft Company

The Douglas D-558 and D-558-2 research airplanes incorporated releasable nose sections to facilitate pilot escape in the case of an emergency. Because the free-nose sections did not have static stability, there was fear that the noses would fall with a steady tumbling-type of motion.

Accordingly, an extensive investigation of the motion of the noses was initiated. In one phase of the work, small models dynamically similar to the full-scale noses were released in the N.A.C.A. 20-ft. Spin Tunnel to study free-fall characteristics. In these low Reynolds Number tests the noses did tumble. Later, in the high Reynolds Number tests on dimensionally similar models that were mounted to spin freely on a shaft, the models could not be made to autorotate. To explain the discrepancy, a modest investigation of the mechanics of tumbling was begun.

It was learned that the motion can be exceedingly complex. Factors that definitely produce a continuous net driving force per revolution are (1) hysteresis effects on the lift coefficient, created by rotation, (2) Reynolds Number effects on the drag coefficient; (3) static net rotating moments characteristic of certain body shapes such as the anemometer; and (4) coupling effect that enables rotational energy to be gained by an otherwise neutral body when allowed to tumble freely in space.

In addition, the following phenomena considerably influence the rotation and possibly contribute to the driving moment: (1) the effect of the shed vortex field on the moments of a rotating body; (2) spinning as with wings in the region where the C_L vs. α curve has a negative slope; and (3) the Flettner rotor effect that may sometimes occur if the body spins about a longitudinal axis.

In the light of the considerations presented herein, it can be seen that tumbling may be greatly influenced by Reynolds Number. In particular, it appears that bodies similar to the D-558 noses will tumble at a low rotational rate. However, means are pointed out by which tumbling can probably be prevented if so desired.

Aerodynamic Coefficients of an Oscillating Airfoil with Control Surface in Two-Dimensional Subsonic Flow

By

A. I. van de Vooren

National Aeronautical Research Institute, Holland

The method of yielding a direct solution in terms of known functions for the aerodynamic forces acting on an oscillating wing in two-dimensional subsonic flow is extended to the case of an airfoil with a control surface hinging about its leading edge. Hinge moment coefficients are calculated for translation and rotation of the whole airfoil, while, for rotation of the control surface lift, pitching moment and hinge moment coefficients are presented. Results are given for Mach Numbers $\beta = 0.35, 0.5, 0.6, 0.7$, and 0.8; for chord ratios $\tau = 0.1, 0.2$, and 0.3; and for a number of ω values smaller than 1.0.

I.A.S. National Meeting Schedule

Twenty-First Annual Meeting—Hotel Astor, New York—January 26–30, 1953

Members or organizations wishing to submit papers for presentation at National Meetings should send outlines or summaries to the Committee no later than 5 months prior to the meeting.

All papers submitted will be considered for publication in the *Journal of the Aeronautical Sciences* or the *Aeronautical Engineering Review*.

All Correspondence should be addressed to:
The Meetings Committee, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

I.A.S. News (Continued from page 17)

News of Members

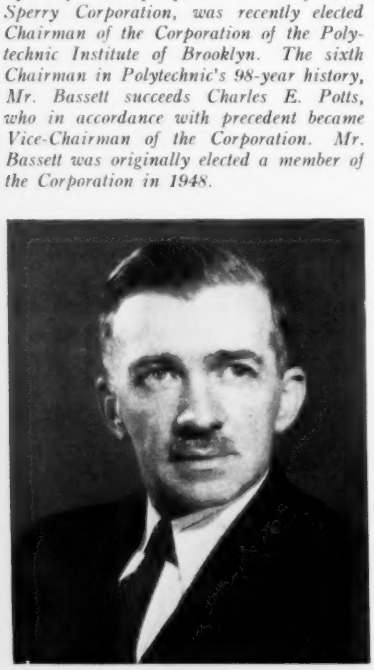
▶ **Rear Admiral Delmer S. Fahrney,** U.S.N. (Ret.) (A.F.), who was Manager of White-Rodgers Electric Company's Eastern Division, has been appointed Director of the company's Aeronautical Department, formed to handle guided missile and drone projects. About 1937, Admiral Fahrney achieved the distinction of being the first project officer in the Navy to handle radio-controlled aircraft. Since that time, he has become so intimately concerned with the conception and development of various guided missiles that he has been dubbed by many as the "Father of the Guided Missile."

▶ **Harold E. Gray** (A.F.), Vice-President, Pan American World Airways, Inc., is now in charge of the company's Atlantic Division. He was formerly in charge of the Pacific-Alaska Division.

▶ **Walter L. Kock** (M.) is on a 2-year leave of absence from his positions as Research Physicist, Hughes Aircraft Company, and Lecturer in Engineering, University of California at Los Angeles. During this 2-year period, Mr. Kock is serving as Consultant in Aeronautical Engineering with the U.S.A.F. in Europe.

ELECTED CHAIRMAN, BROOKLYN POLYTECHNIC

Preston R. Bassett (F.), President, Sperry Gyroscope Company, Division of The Sperry Corporation, was recently elected Chairman of the Corporation of the Polytechnic Institute of Brooklyn. The sixth Chairman in Polytechnic's 98-year history, Mr. Bassett succeeds Charles E. Potts, who in accordance with precedent became Vice-Chairman of the Corporation. Mr. Bassett was originally elected a member of the Corporation in 1948.



NEW POSITION

William J. Pattison (M.) was recently named Director of Sales and Service, AiResearch Manufacturing Company, Division of The Garrett Corporation. He was formerly Assistant to the President of The Garrett Corporation, a position that he held since he joined Garrett in 1948. Mr. Pattison served during World War II with the Black Cat Squadron in the Pacific with the rank of Lieutenant Commander.

▶ **Dr. Richard Lloyd** (M.), Aeronautical Research Engineer, Aero-Mechanics Department, Cornell Aeronautical Laboratory, Inc., has been teaching a first-semester graduate course in Gas Turbines at the University of Buffalo Engineering School. Dr. Lloyd will conduct a graduate course in Compressible Fluids for the second semester.

▶ **Major Ralph J. Nunziato,** U.S.A.F., (M.) has been named Chief of the European Research Office, Air Research and Development Command, U.S.A.F., Brussels, Belgium. This Brussels Office, operating as part of A.R.D.C.'s Office of Scientific Research, will contract for research in Western Europe and monitor Air Force research and development contracts already established in Europe. This office will be the sole research and development contracting and procurement office in Europe for A.R.D.C. and its nine centers located throughout the U.S.A. Prior to this European assignment, Major Nunziato served as Technical Executive to the Director of Research and Development and Chief of the Policy Group to the Deputy Chief of Staff, Development, Washington, D.C.

▶ **Igor I. Sikorsky** (H.F.), Engineering Manager, Sikorsky Aircraft Division, United Aircraft Corporation, was given the 1951 National Transportation Award in recognition of his outstanding contribution in the design and development of the helicopter. The presentation was made by Secretary of the Air Force Thomas K. Finletter (H.M.) at a luncheon meeting of the Washington Chapter of the National Defense Transportation Association on October 23.

▶ **Clarence M. Young** (A.F.), Vice-President, Pan American World Airways, Inc., has been placed in charge of the company's Pacific-Alaska Division.

Members on the Move

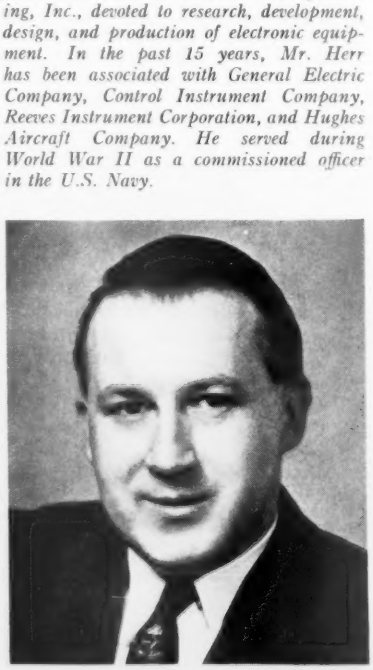
The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are therefore urged to notify the News Editor of changes as soon as they occur.

Donald L. Baker (M.), Project Engineer, Aerophysics Development Corporation. Formerly, Assistant Project Engineer, The Glenn L. Martin Company.

Murray Berkow (M.), Director of Sales Engineering, Republic Aviation Corpora-

HEADS ELECTRONIC COMPANY

Donald Lincoln Herr (M.) was elected President and a Director of the recently formed American Electronic Manufacturing, Inc., devoted to research, development, design, and production of electronic equipment. In the past 15 years, Mr. Herr has been associated with General Electric Company, Control Instrument Company, Reeves Instrument Corporation, and Hughes Aircraft Company. He served during World War II as a commissioned officer in the U.S. Navy.



tion. Formerly, Military Requirements, Republic.

Jules Braunstein (T.M.), Material Review Engineer, Republic Aviation Corporation. Formerly, Stress and Salvage Engineer, Piasecki Helicopter Corporation.

G. Broersma (M.), General Advisor, Planning Bureau, K.L.M. Royal Dutch Airlines, Netherlands. Formerly, General Secretary, Organization for Scientific Research, Indonesia.

W. B. Brower (T.M.), Instructor of Aeronautical Engineering, Rensselaer Polytechnic Institute. Formerly, Research Engineer, Aerophysics Laboratory, North American Aviation, Inc.

Charles Davies (A.M.), T-36 Project Group Leader, Canadair, Ltd. Formerly, Senior Engineer, Engineering Department, Canadair.

Gordon L. Derham (A.M.), now Staff Assistant to the Chief Engineer, Gas Turbine Division, A. V. Roe Canada Limited.

Edward A. Drury (T.M.), Project Engineer, Development Engineering, Jet Division, Thompson Products, Inc. Formerly, Design and Development Engineering Analyst, Power Generators Ltd.

David Eisenberg (T.M.), Production Test Engineer, Hughes Aircraft Company. Formerly, Engineering Designer "B," Hughes.

Dr. Joseph V. Foa (A.F.), Professor, Department of Aeronautical Engineering, Rensselaer Polytechnic Institute. Formerly, Head, Propulsion Branch, Cornell Aeronautical Laboratory, Inc.

Attention Members!

All Members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*.

Gordon C. George (A.M.), Test Pilot, Lockheed Aircraft Corporation. Formerly, Naval Aviator, All Weather Flight Instructor, Naval Air Station, Corpus Christi, Tex.

Leonard Goland (M.), Research Engineer, Forrestal Research Center. Formerly, Project Technical Engineer, Reaction Motors, Inc.

Robert G. Loewy (T.M.), Staff Stress Engineer, Piasecki Helicopter Corporation. Formerly, Associate Research Engineer, Cornell Aeronautical Laboratory.

William A. Miller, Jr. (T.M.), Engine Layout, Chrysler Corporation. Formerly, Rocket Power Plant Installation Draftsman, Bell Aircraft Corporation.

Major Edmund E. Novotny (T.M.), Box 179, HQ 5th AF (Adv.), A.P.O. 970, c/o Postmaster, San Francisco, Calif. Formerly, Air Inspector, 118th Tac. Recn. Wing, Shaw A.F.B., S.C.

Louis G. Raiche (M.), Works Manager, American Car and Foundry Company. Formerly, Chief Inspector, Wright Aeronautical Division, Curtiss-Wright Corporation.

Albert J. Redway, Jr. (T.M.), McDonnell Representative, Dayton Office, McDonnell Aircraft Corporation. Formerly, Field Service Representative, McDonnell.

Captain Alcide Santilli, U.S.A. (T.M.), Physicist, Meteorological Branch, Evans Signal Laboratory, Signal Corps Engineering Laboratories, Army Signal Corps, Fort Monmouth, N.J. Formerly, Physicist, Army Signal Corps, Naval Research Laboratory, Washington, D.C.

Robert B. Sleight (A.M.), President, Applied Psychology Corporation. Formerly Research Scientist for The Johns Hopkins Project, Systems Coordination Division, Naval Research Laboratory.

F. A. Smith (M.), Project Engineer—B-47, Georgia Division, Lockheed Aircraft Corporation. Formerly, Assistant Project Engineer—B-47, Georgia Division, Lockheed.

Emmet T. Ward (T.M.), Stability and Control Engineer, Bureau of Aeronautics, Department of the Navy, Washington, D.C. Formerly, Design Engineer, Bell Aircraft Corporation.

Sidney H. Webster (M.), Sales Manager, Aviation Engineering Corporation. Formerly, with Eclipse-Pioneer Division, Bendix Aviation Corporation.

APPOINTED VICE-PRESIDENT

William W. Wood (M.), Chief Engineer at Link Aviation, Inc., has been appointed Vice-President of Engineering. He joined Link Aviation in 1941 as a Field Engineer. With the company's entrance into the electronics field in 1948, Mr. Wood became Assistant Engineering Manager and 2 years later was made Chief Engineer.

CHANGE OF DUTY

Rear Admiral Theodore C. Lonnquest, U.S.N. (F.) (left) was detached from his post as Deputy and Assistant Chief of the Navy's Bureau of Aeronautics and relieved Rear Adm. Paul E. Pihl, U.S.N. (A.F.) on October 28 as the BuAer's General Representative in the Central District. Admiral Pihl, in turn, was transferred to Washington, D.C., as Assistant Chief of the Bureau of Aeronautics for Research and Development. Admiral Lonnquest in his new post will have charge of all Navy inspection offices located at aircraft plants in the Central District, which covers the area between the Rockies and the Alleghenies and between Canada and Mexico, with headquarters at Wright-Patterson A.F.B., Ohio.

American Helicopter Society News

Southwestern Region Meetings

New helicopter exploits were featured at two recent meetings of the Southwestern Region of A.H.S.

At the first session, held in Grand Prairie, Tex., 110 guests heard speakers from Bell Aircraft Corporation discuss the problems connected with "Operation Longhorn," the 1,234-mile nonstop flight made recently from Hurst, Tex., to Niagara Falls, N.Y., by a Bell Model 17.

Speakers included Robert Lichten, Project Engineer, Frank M. Anthony, Group Engineer, and Elton J. Smith, the pilot of the above-mentioned flight. The engineers talked about the rotor system and mechanical components, airload distribution, blade construction, and other items of technical interest. Mr. Smith described his trip and said the value of it was in the demonstration that small helicopters can be ferried and do not have to be crated for shipment.

At another meeting, T. J. Harriman, Assistant Chief Engineer of Bell, talked about Korean operations and showed slides to a crowd of 120 members and guests. He had recently been on a 2,000-mile tour of the Far Eastern Command.

Mr. Harriman's talk was devoted to hitherto unemphasized aspects of military utilization of helicopters in two major phases. First, the particular new uses being explored for the helicopter, and, second, the particular design requirements and their significance, weight and cost-wise, occasioned by the new uses. Typical uses that required design improvements include rapid deployment and recovery of specialized rocket launcher teams, assault operations from the sea and in mountainous terrain, long-range rescue and box-canyon pickups at altitude, and night and all-weather operations. Design requirements outlined included performance increases in altitude, speed, and stability; maintenance improvements in component design, ready disassembly, and weathering protection; and equipment advances toward night and all-weather flying, controlled heating, and assistance to evacuees.

The speaker's conclusion was that the rate of exploitation of the helicopter is still far in advance of helicopter development, thus providing an ever expanding initiative for the helicopter industry.

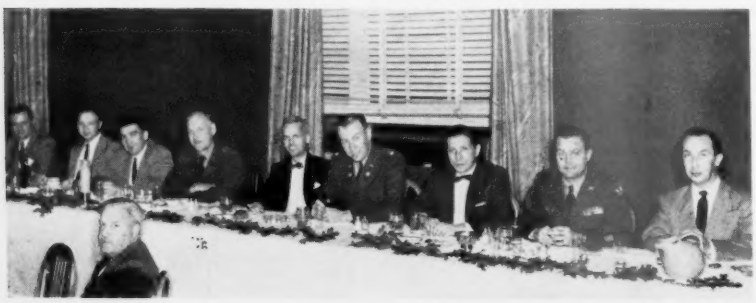
Between the two meetings, 80 members of A.H.S. and I.A.S. attended an Open House program at Bell's new Texas plant.

Regional Vice-President John D. Beadling recently announced the election of Samuel Vitellaro as Treasurer and Frank M. Anthony as Secretary.

Contributors to American Helicopter Society News are urged to keep in mind that it takes about 6 weeks for copy to get in print. This page needs material on the activity of regional groups and individual members, but it must be in the hands of the publicity chairman not later than the 5th of the month to appear in the issue of the second month following. Address contributions to Claude O. Witze, Piasecki Helicopter Corporation, Morton, Pa.

A.H.S. PHILADELPHIA MEETING

Seated at the head table, left to right, are: Harry Lounsbury, Executive Secretary, A.H.S.; Lt. Comdr. Walter C. Kenyon, Assistant Chief, Office of BuAer Representative, Morton; A.H.S. President T. R. Pierpoint, Piasecki Helicopter Corporation; Col. William B. Bunker, Office Chief of Transportation, Department of the Army; Frank K. MacMahon, Piasecki; Lt. Col. A. B. Evans, Assistant Chief, Air Transport Division, Department of the Army; Monroe R. Brown, Piasecki; Col. Douglas L. Rundquist, Head, Regional U.S.A.F. Procurement Office; and Edward Miller, Kellett Aircraft Corporation.



Southeastern Region Meeting

Helicopter operators, present and potential, were warned to respect other people's property if they want to protect their own best interests, in a recent talk before the Southeastern Region of A.H.S. in Washington. The guest was Robert B. Boyle, Deputy General Counsel of the Civil Aeronautics Administration, who shared the platform with Frank N. Piasecki, Chairman of the Board of Piasecki Helicopter Corporation, and Charles W. Wendt, of All American Airways, Inc.

Mr. Boyle, reviewing some legal aspects of commercial helicopter operation, pointed out that the very things that make the machine unique—its ability to fly low and slow and to hover—make it potentially the greatest offender of persons on the ground.

In order to avoid the enactment of overly restrictive laws by communities that the helicopter is trying to serve, Mr. Boyle called upon the industry to temper requests for freedom from the operating restrictions of airplanes with consideration of the "other fellow's" rights.

The speaker also pointed out that the low-speed flight ability of the helicopter is being used as the justification for release of the helicopter from the traffic pattern and visibility rules applied to airplanes. Although the helicopter, flying alone in the air, may be unnecessarily restricted by existing Visual Flight Rules, it may be necessary to apply the same V.F.R. conditions to both fixed and rotary wing aircraft to protect the helicopter from the airplane, he said.

Mr. Wendt said that the helicopter was suited to the short-leg operations pioneered by All-American Airways.

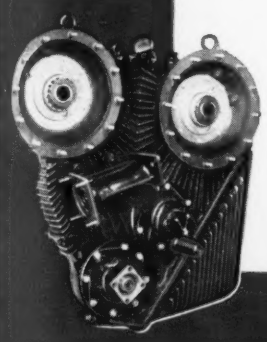
Mr. Piasecki reviewed the large number of problems associated with the commercial application of helicopters such as the design of heliports, some of the economics of commercial helicopter operation, and the requirement for twin engines in any helicopter used for over-city passenger service.

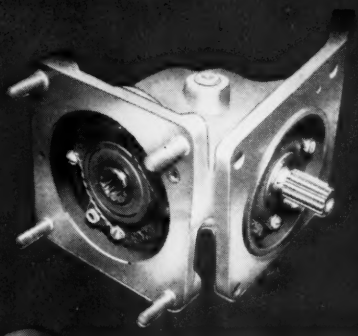
A.H.S. Membership

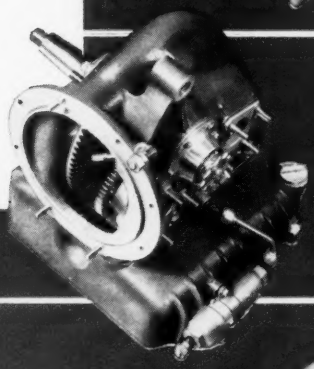
The American Helicopter Society's membership drive has hit high gear. Harry Lounsbury, Executive Secretary, reports that 647 members now are listed, and applications still are coming in. Both he and President T. R. Pierpoint believe the society will pass the goal of 1,000 before the annual forum in May.

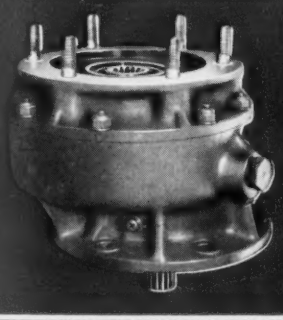
(*Continued on page 69*)

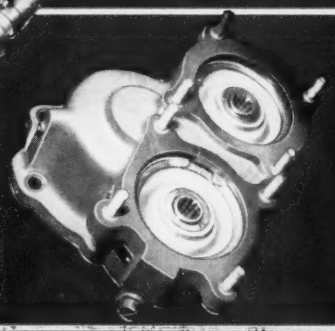
HEADQUARTERS
FOR
AIRCRAFT ACCESSORY DRIVES

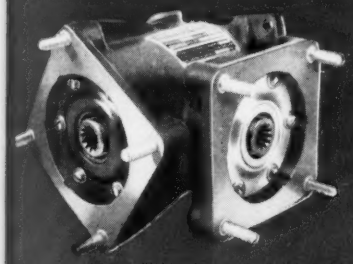


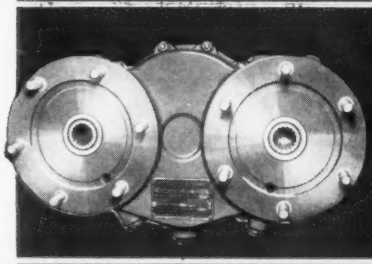


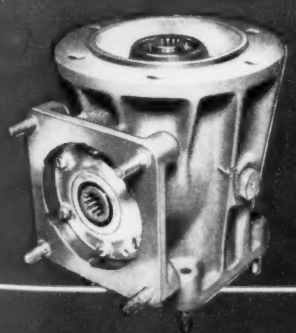


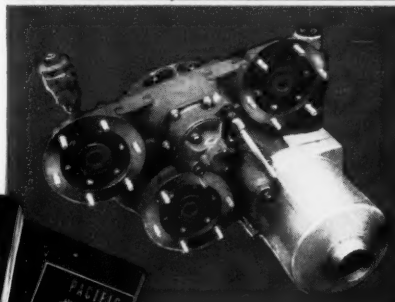












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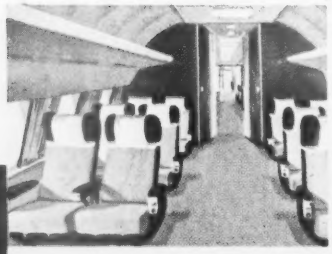

Forward Cabin—Cabin No. 1 has fully reclining, adjustable chairs—deep cushioned, roomy, relaxing. As throughout the plane here is the comfort appreciated in non-stop travel.

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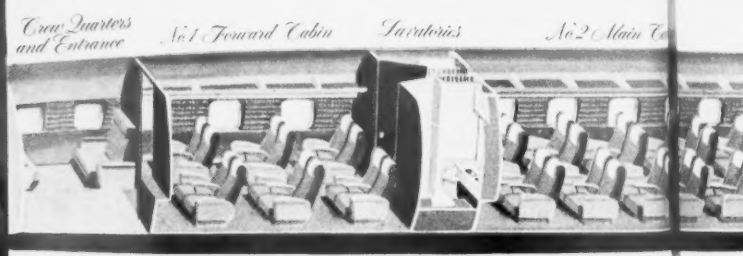
The Super Constellation is the longest, largest, finest airliner ever built—with 4 superbly appointed passenger cabins, a luxurious lounge, galley and bar, 4 lavatories, crew's quarters, pilot's cabin—all air conditioned. Compartmentization creates a solid feeling of sturdiness never before achieved in any airliner.



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A New, Record-Breaking Network

When Korea happened, the already heavy demands on Eclipse-Pioneer's services multiplied overnight . . . and also became tremendously more complex than ever before. A key step in coping with this new responsibility was the creation of a vast network of sub-contractors—a network that was inaugurated a short three months after the start of Korea and has since grown to include 23 complete unit sub-contractors and over 2300 first tier parts sub-contractors. This network, coupled with our own greatly enlarged facilities, represents a 2½ times faster rate of expansion than that of the comparable pre-Pearl Harbor defense build-up period, and has made possible an acceleration of Eclipse-Pioneer production output to a record 514% of our pre-Korea level. Despite these records, we are continuing to increase the tempo of our overall program—and will continue to do so until we catch up fully with our unprecedented demand.

PRECISION PRODUCTS* MADE BY ECLIPSE-PIONEER

- Automatic Pilot and Flight Path Control Equipment
- Airplane and Engine Instruments
- Flight and Navigation Instruments
- Power Supply Equipment
- Air Pressurization and Ice Elimination Equipment
- Engine Starting Equipment
- Oxygen Equipment
- Precision Components for Servomechanism and Computing Equipment
- Sand, Permanent Mold and Die Castings of Magnesium and Aluminum
- Plaster Mold Castings

Manufacturing capacity is now available for a great many models of these products.

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WORLD'S LARGEST PRODUCER OF AVIATION INSTRUMENTS AND ACCESSORIES

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Mr. Lounsbury's efforts bore fruit in October, when the New England Region fell in line with some real cooperation. Applications were sent out to launch a hunt for members in each major helicopter plant in the area. Next, the Western and Midwestern Regions will start the ball rolling.

Recently, Thomas Harriman, of Bell Aircraft Corporation, reported on his activity as Membership Chairman and disclosed that 285 members were added to the roster in the year and a half before Mr. Lounsbury was appointed.

Mideastern Region Meeting

The Mideastern Region of A.H.S. held its first fall meeting on October 16 at the Penn Sheraton Hotel in Philadelphia.

Guest speaker for the evening meeting was Col. William B. Bunker, Office Chief of Transportation, Department of the Army. Colonel Bunker spoke on "Army Helicopter Transportation." Frank MacMahon, of Piasecki Helicopter Corporation, introduced the speaker.

Among other military guests present at the head table were: Lt. Col. A. B. Evans, Assistant Chief of Air Transport Division, Department of the Army; Lt. Comdr. William Kenyon, Assistant Chief, Office of BuAer Representative, Morton; and Col. Douglas L. Rundquist, Head of the Regional U.S.A.F. Procurement Office.

Prior to Colonel Bunker's speech, A.H.S. President Pierpoint introduced the new Executive Secretary, Harry Lounsbury, to the group of approximately 200 A.H.S. and I.A.S. members present.

CLAUDE O. WITZE
Publicity Chairman, A.H.S.

Corporate Member News

• **American Bosch Corporation . . .** A new long-lived ignition system that is based on a company-developed new-type pulse-generator design has been announced. This ignition system is said to represent "a significant step in making possible substantially more efficient operation of high-compression natural-gas engines." This new self-powered generator, designated as the American Bosch Pulse Generator MGC, is capable of producing output potentials up to 30,000 volts. It is a comparatively large unit with a diameter of about $11\frac{1}{4}$ in. and a height above its mounting of approximately $12\frac{1}{2}$ in. It supplies "accurately timed low tension electrical pulses which are stepped up to the required spark potential by means of either single or double ignition transformers mounted on each cylinder near the spark plug or plugs. The ignition transformers are new American Bosch CLQ (single-spark) or CLP (two-spark) types designed for use with the pulse generator. They are hermetically sealed, oil filled, and have closed cores." No breakers are in operation during running; they are used for starting only. No distributor is employed. At operating speeds the rotor and two ball bearings are the only moving parts. The development of this particular ignition system stemmed from an urgent demand for cheap power from natural gas. . . . Donald H. Spicer was recently elected Vice-President—Manufacturers Sales for the corporation.

• **The Cleveland Pneumatic Tool Company . . .** Elmer W. Krueger has been made Vice-President of the company.

• **Consolidated Vultee Aircraft Corporation . . .** A production order to build the F-102 delta-wing interceptor for the U.S.A.F. was officially disclosed last October 14. The F-102 is designed for "very high speeds in the stratosphere and incorporates significant improvements in electronics and armament." No performance or production figures were released.

• **Cornell Aeronautical Laboratory, Inc. . . .** Cornell's Industrial Division is operating from new facilities and offices. A recent addition to the applied research organization, the division has moved into quarters in a new annex to C.A.L.'s main building. The Industrial Division's research program, after 6 months, included some 20 active contracts valued at over $500,000.

• **Douglas Aircraft Company, Inc. . . .** The X-3 successfully completed its first flight, which took place on October 20 at Edwards A.F.B., Calif. This experimental aircraft has a long slender fuselage and straight stubby wings. It is powered by two Westinghouse J-40 jet engines. The X-3 is said to have an ultimate design speed of Mach 3 at altitudes up to 100,000 ft.

• **Eaton Manufacturing Company . . .** A Type II Fuel Filler Cap that meets all test specifications of MIL-C-7244 is now being produced at Eaton's Stamping Division. The cap design features the desired safety "pop-up" requirement in addition to the quick sealing engagement that is accomplished by means of two revolutions of the engaging screw. The adapter can be shaped to conform with various tank contours and, because of its shallow construction, can be adapted whenever high nesting ratios are required. This CM-2432 Cap and Adapter Assembly, which is of an all-steel construction, provides maximum strength with a total weight of only 1 lb., 5 oz.

• **Fairchild Engine and Airplane Corporation, Al-Fin Division . . .** Two domestic and two foreign firms have been licensed to use the Al-Fin process of joining aluminum and its alloys to steel and cast iron or to nickel and titanium. The companies

P.A.A. TO PURCHASE COMETS

Pan American World Airways, Inc., announced on October 20 that its Board of Directors had approved the exercise of Pan American's option for the purchase of three de Havilland Comet Series 3 jet transports for delivery in 1956. Included in this de Havilland-Pan American contract is a 2-year option for seven additional jet transports with a 1957 delivery date. A preliminary model of the Comet Series 3 is shown in the photograph below. This jet transport will be powered by four Rolls-Royce Avon R.A. 16 axial-flow turbojet engines, each capable of developing 9,000 lbs. of thrust. It will have accommodations for 58 first-class or 78 tourist-class passengers. It will cruise at 500 m.p.h. at altitudes up to 45,000 ft. and will have a range with full pay load of some 2,700 statute-miles. The fuel capacity will be 9,700 U.S. gal.

concerned in the latest licensing agreement are Thompson Products, Inc.; National Steel and Shipbuilding Corporation; Etablissements J. Floquet, of France; and W. & W. Schenk, of Germany. This brings to 18 the number of companies licensed by Al-Fin to use this process.

• **Fairchild Engine and Airplane Corporation, Stratos Division . . .** A new cabin supercharger developed from the basic Stratos supercharger has been announced. This unit supplies 62 lbs. of air per min. to the aircraft cabin and can maintain maximum allowable cabin-pressure differential to all operating altitudes. The new supercharger, Model S60-11A, features, among other things, a "V"-type mounting flange arrangement that speeds installation and similar duct-clamping arrangements on the inlet and outlet. All of the supercharger's oil lines have been replaced by internal, drilled passageways, with the exception of two short lines to the pilot's control solenoid. A positive "flyball" overspeed control governor limits the impeller speed.

• **Fletcher Aviation Corporation . . .** The Fletcher single-engined FD-25 Defender will be built in Japan under a licensing agreement between Fletcher and Toyo Aircraft Company, of Tokyo, Japan. The prototype FD-25 will be shipped to Japan where it will be reassembled for flight demonstrations and for use by the Japanese firm as a pilot production model. Sales of the FD-25 will be restricted to noncommunist countries.

• **General Electric Company . . .** An announcement from the Aviation Division states that three different types of auxiliary power systems for future commercial jet air liners are now being developed. G-E is now also working to improve two jet-engine models that have received C.A.A. approval for commercial use and to develop components for use in jet transports whenever they are built.

• **The B. F. Goodrich Company . . .** Tires for jet air liners have been developed and are now undergoing tests. Indications are that tires for jet air liners may be of the tubeless type, which, it is said, are cooler running than conventional types. Air pressures in jet-air-liner tires will be approximately 135 lbs. per sq.in.

• **Hamilton Standard Division, United Aircraft Corporation . . .** As the result of a licensing agreement between Plessey Company, Ltd., of England, and Hamilton Standard, the latter company will place in production this year the Plessey-developed liquid-fuel starter for turbine engines. This new starter type, said to be the first of its kind to be manufactured in this country, uses a special fuel as the primary source of power. The fuel is stored in an easily refilled tank from which it is pumped to the starter. A single push-button control causes the electric ignition of the fuel, and combustion products cause a small turbine wheel to spin which, through reduction gearing, cranks the engine.

• **The International Nickel Company, Inc. . . .** The consolidation of the advertising sections of the Nickel Sales and Inco Nickel Alloys departments was recently accomplished. Under this new setup, R. L. Lloyd and R. A. Wheeler are serving as General Manager of Advertising and Assistant General Manager of Advertising, respectively.

• **The M. W. Kellogg Company . . .** A new catalytic desulfurization process, known as Autofining and capable of eliminating 90 per cent of the sulfur content in sour middle distillates without appreciable product loss, is now available through Kellogg. This availability is a result of a licensing arrangement concluded with Anglo-Iranian Oil Company, which developed this process over a period of several years.

• **Lockheed Aircraft Corporation . . .** The Super Constellation, powered with four turbocompound engines, made its first flight, as scheduled, early in November at the Lockheed Air Terminal, Calif. The particular ship making this flight—the first for any turbocompound-powered transport—was built for military service as a U.S.N. R7V-1. It can carry 106 passengers, up to 19 tons of cargo, or 73 battle casualties on stretchers. The first commercial version of this aircraft will be ready early this year. . . . A 230-ton tower and treadmill is being built by Lockheed research specialists which, by simulating aircraft take-offs and landings, will help eliminate shimmy from the landing gears. This equipment consists of three primary parts: (1) a 21-ft. tower for mounting landing gears and for guiding their up-and-down movement; (2) 30-ton weights applied directly to the gear; and (3) a

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COMPACTNESS . . .
PERFORMANCE . . .
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FRACTIONAL HORSEPOWER
MOTORS

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Compactness . . . low weight . . . excellent performance — these are some of the other advantages obtained with Lamb Electric Motors, because they are *specially engineered* for the application.

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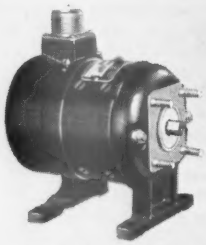
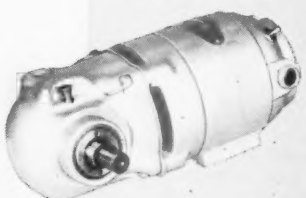


Intermittent high torque motor with low weight factor; for aircraft and many other applications.



Space factor in this power unit is minimized by having output shaft at right angles to motor shaft.

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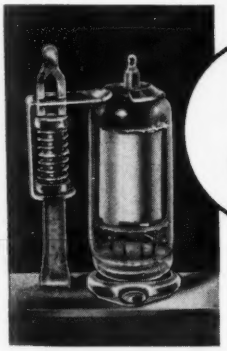
AMERICA'S *Finest* PRODUCTS

Lamb Electric
SPECIAL APPLICATION
FRACTIONAL HORSEPOWER MOTORS

BIRTCHER
TUBE CLAMPS
Hold Tubes in Sockets under all Vibration, Impact and Climatic Conditions

83 VARIATIONS FOR STANDARD TUBES



NEW CLAMP FOR MINIATURE TUBES

You can't shake, pull or rotate a tube out of place when it's secured by a Birtcher Tube Clamp. The tube is there to stay. Made of Stainless Steel, the Birtcher Tube Clamp is impervious to wear and weather.

BIRTCHER TUBE CLAMPS can be used in the most confined spaces of any compact electronic device. Added stray capacity is kept at a minimum. Weight of tube clamp is negligible.

Millions of Birtcher Tube Clamps are in use in all parts of the world. They're recommended for all types of tubes: glass or metal—chassis or sub-chassis mounted.

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Write for samples, catalogue and price lists.

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10-ft. diameter steel cylinder that spins below. The landing-gear wheels roll on the periphery of the revolving drum to simulate landing or take-off speeds of more than 150 m.p.h. Power for rotating the drum is supplied by a 375-hp. diesel engine. . . . The U.S. Air Force has placed its ninth order for the Lockheed T-33 jet trainer.

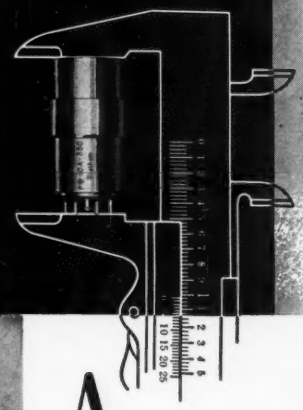
• **Loewy Construction Company, Inc. . .** Emery B. Kerekes was named Assistant to the Vice-President of Hydropress, Inc., and its subsidiary, Loewy Construction Company.

• **Lord Manufacturing Company . . .** Two of the company's key officials, George E. Tubb and Richard C. Henshaw, A.F.I.A.S., have been advanced to new positions. Mr. Tubb is now Vice-President in Charge of Sales. Previously, he had served as General Sales Manager since he joined Lord in 1949. Mr. Henshaw is now Manager of Engineering. He has been with Lord since 1938, having served successively during the intervening period as Engineer, Chief of Product Engineering, and Manager of Product and Sales Engineering. . . . Charles L. Freel, M.I.A.S., is Manager—Field Engineering for Lord. . . . Because of a clerical error in preparing the Classified List of I.A.S. members by company affiliations in the 1952–1953 Roster of Members, the name of Willem D. Van Zelm, M.I.A.S., was carried on page 162 under the Lord Manufacturing Company listing. Mr. Van Zelm is not connected with Lord but is Chief Designer and Owner of his own company.

• **Minneapolis-Honeywell Regulator Company . . .** Two new 400-cycle synchronous vibrators that have been specially designed to convert d.c. signals to a.c. for aircraft control purposes were recently announced by the Aeronautical Division. Both models can also be used as rectifiers. Model WG178A is designed for a supply voltage of 115 volts, 400 cycles per sec., while Model WG178B takes 12.6 volts, 400 cycles per sec. Power consumption is 0.7 and 0.25 watt, respectively.

• **North American Aviation, Inc. . . .** An electrical-optical instrument that offers instant data on the proper speed at which an airplane must descend to effect a safe carrier landing has been developed by North American and adopted by the U.S. Navy. This instrument, Touchdown Rate of Descent Indicator, nicknamed "TRODI," is being produced by North American's Electro-Mechanical Engineering and Manufacturing Departments. TRODI measures the rate of descent by sending out two parallel beams of light, thin vertically and wide horizontally. They are 1 ft. apart. A mirror system on the incoming plane cuts the top beam, reflecting the light back to a photoelectric cell, which starts an electrical charge into a condenser. The descending aircraft then cuts the second and lower beam, reflects it, and stops the charge going into the condenser. The electrical charge stored during the interval between beams is quickly translated by TRODI from voltage into rate of descent in feet per second. This instrument is said to measure rate of descent with an accuracy of 0.4 ft. per sec.

subminiature pressure transducer



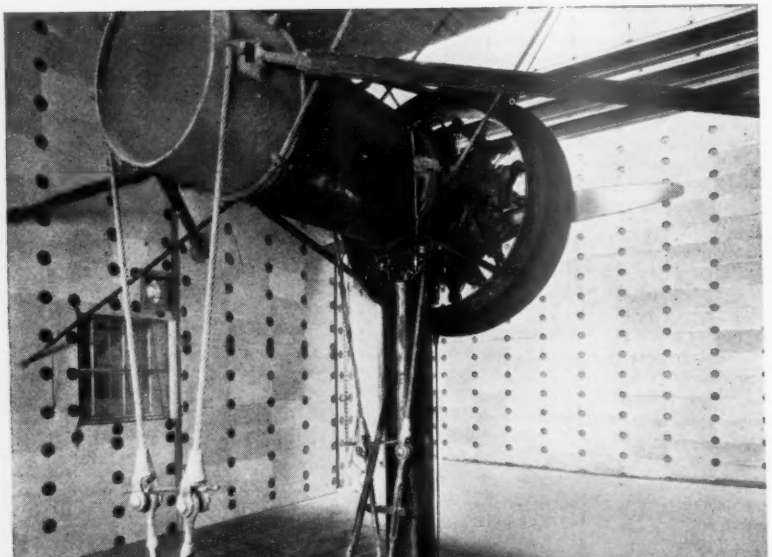
A pressure transducer weighing less than 1 ounce provides the accuracy and stability of the familiar unbonded strain gage, unaffected by reduction in size. The design allows flush mounting of the ½ inch diameter diaphragm. Natural frequencies, depending on range, extend to several kilocycles per second, yet the accuracy of ± 1% of full scale holds for static as well as dynamic measurements. The electrical output of the four active arm transducer bridge will operate oscillograph galvanometers directly.

The Model P81 Subminiature Pressure Transducer is described fully in Bulletin No. 3.4, available upon request.

Statham LABORATORIES
Rancho Station • Los Angeles 64, Calif.

ISC MAKES HISTORY...

WITH THE FIRST SUCCESSFUL TEST CELL FOR SILENCING AIRCRAFT PROPELLER TEST NOISE



Industrial Sound Control, collaborating with engineers of Hamilton Standard, Division of United Aircraft Corporation, installed at Hamilton in 1936 what is believed to be the first successful acoustical test cell in the United States. The photograph is of interest because it points up so dramatically the extent of present day progress.

The aircraft industry has made phenomenal strides since 1936, with a tremendous increase in horsepower and thrust, and an even greater increase in noise. ISC has paralleled these developments with constantly improved materials and techniques . . . and has continually added to its engineering skill and experience.

A recent example is ISC's new CERAM-ACOUSTIC heat- and corrosion-resistant treatment. An exclusive baked-on ceramic coating, which may be applied to ISC's "Soundmetal" panels, or to the new and revolutionary *Soundstream ® units, it withstands extreme temperatures without the need for cooling water.

ISC will design, engineer, manufacture and erect complete testing facilities, tailored to meet your specific requirements. Put ISC's "Silence Service" to work for you.

Foreign Licensees: Cementation (Muffelite) Limited, London
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*Developed by BLEN Corporation — engineered, manufactured and installed by ISC.

SILENCE SERVICE

Industrial Sound Control Inc.

45 Granby Street, Hartford 12, Conn.

2119 SO. SEPULVEDA BLVD., LOS ANGELES, CALIF.

• **Northrop Aircraft, Inc. . . .** A new medium-size high-performance extreme-temperature chamber, designed to test F-89D components, can simulate temperatures for any spot in the world in a matter of minutes. The air temperature in the chamber can be lowered from 70° to −85°F. in 10 min. and can be raised from 70° to 180°F. in 7 min. The chamber was designed for operation at any temperature between −100° and 250°F. Low temperatures in this chamber are obtained by a dry ice-methanol system, and high temperatures are accomplished by the fan circulating air through a group of finned-type electric heaters. . . . An exclusive license has been awarded by Northrop to Narmco Resins and Coatings Company to manufacture and market a Northrop-developed metal-plastic adhesive for bonding Styrofoam to metal or other surfaces.

• **Pan American World Airways, Inc. . . .** Plans have been announced for the construction of a $500,000 mechanized engine-overhaul shop at the San Francisco International Airport. In this shop, which is scheduled for completion in May of 1953, major engine overhauls for P.A.A.'s Pacific-Alaska Division fleet will be accomplished. The engines slated to be overhauled at this base include the Pratt & Whitney R-4360, R-2800, and R-2000 power plants. . . . Several executive changes within the organization were recently announced. Harold E. Gray, A.F.I.A.S., who has been Vice-President in charge of the Pacific-Alaska Division since 1949, was named Vice-President in charge of the company's Atlantic Division. Clarence M. Young, A.F.I.A.S., a Pan American Vice-President succeeds Mr. Gray in the Pacific-Alaska Division post. At the same time, Humphrey W. Toomey, formerly Manager of the Latin American Division, has been elected a Vice-President of the company with headquarters in Rio de Janeiro. Mr. Toomey was succeeded in his managerial post by Edwin Drescher.

• **Pratt & Whitney Aircraft Division, United Aircraft Corporation . . .** The new North Haven, Conn., branch plant was formally dedicated on November 16. This 700,000 sq.ft. plant, which occupies a 161-acre tract of land, manufactures major parts for R-4360 Wasp Major engines. The eleven complete manufacturing departments that were moved from the main East Hartford, Conn., plant have since been divided into 18 departments at North Haven. . . . The American Legion presented P. & W. with its annual National Award in recognition of the company's program for employment of disabled veterans and for its overall selective placement program by which persons regarded as handicapped are carefully placed in productive jobs. The presentation was made on last October 14 during a ceremony at East Hartford, Conn.

• **Simmonds Aerocessories, Inc. . . .** A new 4-page folder entitled *The Mechanical Push-Pull—A Remote Control for Industrial Use* is available gratis from the company. Illustrated with photos, drawings, and tables, the folder provides a design engineer with data in planning new lay-

outs for applications where precision control, flexibility, and ruggedness are of importance.

• **Summers Gyroscope Company . . .** The Santa Monica plant is now being retooled for the production of a newly designed precision telemetering gyro that is said to have a drift rate of only 0.25° per min. Factory deliveries of this gyro, which weighs 3.5 lbs., are expected to get under way early in 1953.

• **Trans World Airlines, Inc. . . .** A special survey flight of the route between Bombay and Tokyo was made recently by the company. During this flight, air-line officials made a detailed study of the traffic potential, as well as airport and airways facilities, along the 4,232 miles between Bombay and Tokyo.

• **Union Carbide and Carbon Corporation . . .** Fred H. Haggerson, Chairman of the Board, died on October 14 after a brief illness. Mr. Haggerson had been associated with Union Carbide for 33 years, during which time he served successively as Vice-President, Director, President, and Executive Committee Member.

• **United Air Lines, Inc. . . .** The company's annual report to shareholders has been selected for the sixth consecutive year as the best issued by any domestic air line in the *Financial World*'s international survey of company reports.

• **Western Gear Works . . .** A new sales and engineering office was opened recently at 500 South Ervay Street, Dallas, Tex.

I.A.S. Sections

Atlanta Section

Edith Hall Lively, *Secretary*

The recently organized Atlanta Section started off the 1952–1953 season with a dinner meeting on October 9. David Berry, Organizing Chairman, opened the meeting by introducing the new officers who compose the first permanent slate. They are: Chairman, George W. Baughman; Vice-Chairman, George K. Williams; Secretary, Edith H. Lively; and Treasurer, John K. Harper. Mr. Berry then turned the meeting over to Mr. Baughman who welcomed the 75 members and guests assembled to hear Carl J. Wenzinger, of the St. Louis Section, discuss the Air Force facility at Tullahoma.

Mr. Wenzinger prefaced his talk by stating how far the United States was behind Germany at the close of World War II. To offset this and to assist industry in the development of new aircraft, the Arnold Engineering Development Center was created. After extensive investigation, a 33,000-acre TVA site in Tennessee was selected and developed. One company controls the operation of the center, with an advisory board.

Mr. Wenzinger showed slides of the area and of the various facilities now in use. At the close of his talk, time was given for questions and general discussion.

Boston Section

E. A. McBride, *Secretary*

"Cold Weather Transportation Operations" was the topic discussed by Major Gerald D. Knutson at the annual dinner meeting of the I.A.S. Boston Section, held at the Thomson Club, Nahant, Mass., on May 28. Major Knutson, Commanding Officer, 1255th A.T.C., ATLD, M.A.T.S., Westover Air Force Base, Westover, Mass., discussed some most interesting problems resulting from the cold-weather effects on engines, structures, communications, and navigation.

During the social hour before the dinner, 70 members and guests participated in a "Mystery Twelve Contest." The object was to identify the true names of twelve disguised persons who had been assigned such names as Mr. Air Frame, Mr. Jet Engine, etc. John B. Tucker was presented with a beautiful silver B-47 ashtray for the first prize.

The following officers were elected to serve during the coming year: Chairman, R. L. Bisplinghoff; Vice-Chairman, J. D. Morrison; Secretary, E. A. McBride; and Treasurer, E. E. Larrabee.

The speaker concluded his program with a survival film entitled *Land and Life in the Arctic*, and a brief question period followed.

Buffalo Section

George B. Melrose, Jr., *Secretary*

The opening meeting of the 1952–1953 season was held on October 22 at the Westbrook Hotel. Results of the election were announced by Dick Koegler, Chairman of the Nominating Committee, and the new slate of officers was installed as follows: Chairman, Alexander Krivetsky; Vice-Chairman, William Champney; Secretary, George Melrose; and Treasurer, Alison Arnold. Chairman Al Krivetsky presided at the meeting and introduced the speaker. The meeting was attended by approximately 80 members and guests.

George D. Ray, Chief of Preliminary Design at Bell Aircraft Corporation, spoke on his recent inspection tour of Korea. The purpose of the tour was to allow representatives of the aircraft industry to observe the use of military equipment under battle conditions and to aid them in evaluating the means by which to satisfy the requirements and needs of the Armed Forces. Mr. Ray's descriptive outline of the 20,000-mile 3-week tour was amply illustrated with colored slides of Japan, Korea, and Navy Task Force operations. The slides included a brief description of the forward air-observers post he visited and showed the extensive use to which the helicopter is being put. He described the methods used for evacuating front-line casualties to field hospitals and the techniques used to rescue downed fighter pilots from behind enemy lines by helicopter. Mr. Ray included many interesting slides of the life and customs in Japan today and scenes of urban and rural activities and religious shrines.

Mr. Ray reported that the morale of the fighting forces is generally good and expressed the opinion that one of the major problems is the reduction of time between the drawing board and the delivery of equipment to the fighting troops.

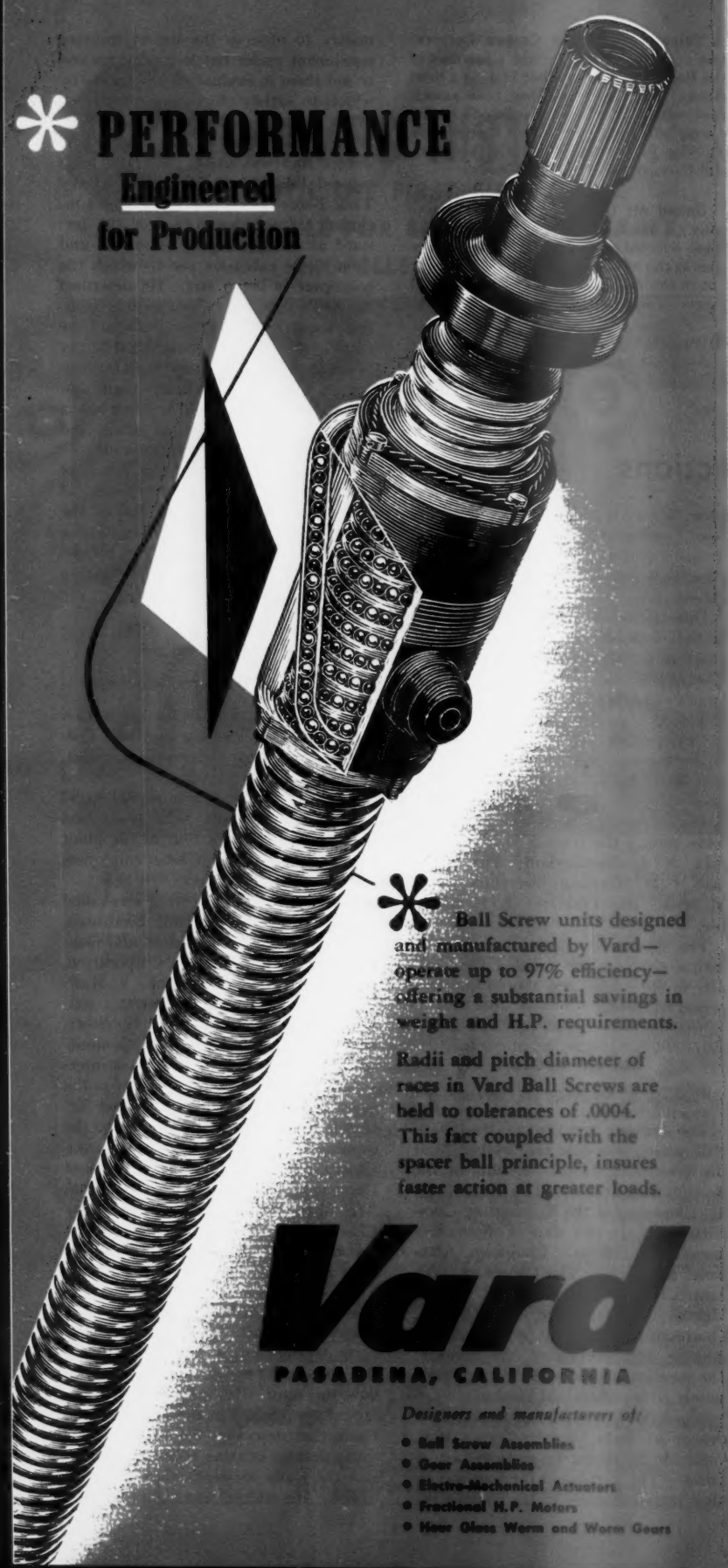
Chicago Section

Charles L. Bonnette, *Secretary*

On November 5, the Chicago Section held its annual meeting at Globe Corporation, Aircraft Division, in Joliet, Ill. At 6:30 p.m., a company-sponsored cafeteria-style dinner was served to 82 members and guests. The group was then conducted on a tour of the plant facilities by several Globe employees who are I.A.S. members.

At 8:00 p.m., the meeting was called to order by Dr. H. L. Hull, Chairman. E. A. Cooper, Vice-President and General Manager of Globe Corporation, Aircraft Division, and Dr. H. V. Hawkins, Director of Engineering, welcomed the group. Alfred F. Stott, Vice-Chairman and Program Committee Chairman, summarized a most interesting program for the remainder of the year. Benedict M. Vinicky, Chief Research Engineer of Globe, presented the evening's speaker, E. A. Gimalouski, Chief Engineer, Pioneer Parachute Company, Inc., Manchester, Conn. Accompanying Mr. Gimalouski was Charles Irons, Vice-President of Air Associates, Inc., Pioneer's Midwest sales agents.

Mr. Gimalouski presented an informative address entitled "Parachutes for Today's Aircraft." He outlined the early development of the parachute by the pioneers of aviation and explained how the most significant advance has been accomplished in the last 10 years. He further described the various parachute designs existing today, their use, and the loads to which they are subjected. His address was highlighted by


* PERFORMANCE
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* Ball Screw units designed and manufactured by Vard—operate up to 97% efficiency—offering a substantial savings in weight and H.P. requirements.
Radii and pitch diameter of races in Vard Ball Screws are held to tolerances of .0004. This fact coupled with the spacer ball principle, insures faster action at greater loads.
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Designers and manufacturers of:
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• Fractional H.P. Motors
• Hour Glass Worm and Worm Gears

the showing of a group of slides and a motion picture depicting the operation of the described parachutes.

Cleveland-Akron Section

R. E. Bolz, *Secretary*

The meeting of October 21 was held in the University Club in Akron, Ohio, and was the second meeting of the year for the Cleveland-Akron Section. The main speaker, Dr. R. F. Mettler, was introduced by our Co-Chairman, Harrison Chandler, following an introductory talk by Mr. Cohill, Assistant to the President of Firestone Tire and Rubber Company. Dr. Mettler is Associate Head, Systems Department, Research and Development Laboratories, Hughes Aircraft Company.

Dr. Mettler, whose subject was "Electronics in Aviation," discussed complex electronic systems, including radar and automatic computing components which have recently become an essential part of military aircraft, and, according to Dr. Mettler, will assume an increasingly important role in the commercial aircraft of the future. The example that he chose for illustrating the need and use of electronics in military aircraft was the all-weather interceptor. Here, the interceptor must be required to take off from the home base on the approach of an enemy bomber; it must rise to about a 40,000-ft. altitude in a very short time; it must recognize the position of the enemy bombers; and it must fly to the interception of these and, on contact with the bombers, must perform a flight path that allows projectiles to be launched against the bomber with a reasonable chance of a successful kill. Coupling these requirements with the very high speed of both the bomber and the interceptor, it becomes impossible for the pilot to control the airplane with the exact timing necessary. Therefore, many of his operations must be replaced by electronic systems, including radar coupled with computing systems and those, in turn, controlling hydraulic systems to the fire-control mechanisms.

The fundamental facts that require that such complex electronic equipment be carried in a modern interceptor in order to make it a useful weapon were carefully reviewed by the speaker, and the basic operating principles of the interceptor system were discussed. The bulk of the equipment and circuit design problems encountered in these electronic systems are extremely difficult, and progress will very likely be slow.

Dr. Mettler's discussion included (1) the integration of the air-frame and electronic design for the purpose of ease of maintenance, (2) the radome design for high-speed flight, (3) the serious

cooling problems associated with electronic equipment in a supersonic airplane whose screen temperature is much higher than the allowable temperature of the electronic gear, (4) acceptability problems, and (5) fire-control problems.

A brief picture of future trends was given with particular reference to the reliability and complexity problems. In this respect, decreasing the size of the electronic equipment, although affecting the decrease in weight and space requirements, increased the maintenance problems. Dr. Mettler further discussed the future importance of the transistor and predicted that, in 5 to 10 years, the transistor would become an integral part of all electronic systems and many revolutionary changes could be expected.

Detroit Section

John Lees, *Secretary*

The following persons will serve as officers of the Detroit Section for 1952–1953: Chairman, Kenneth E. Smith; Vice-Chairman, Lambert Chapin; Secretary, John Lees; and Treasurer, George Martin.

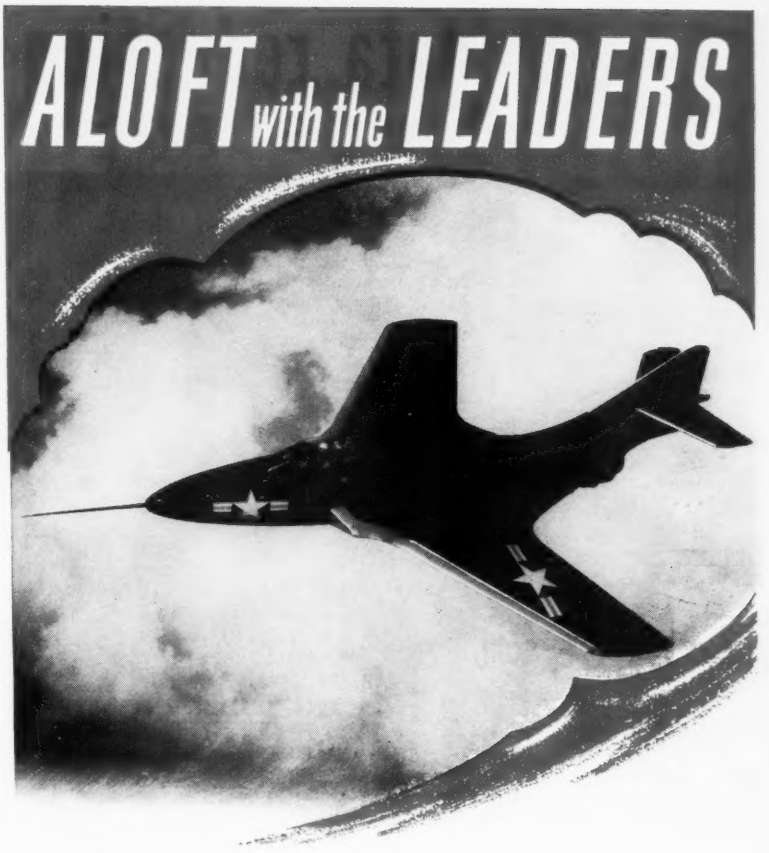
Hagerstown Section

R. E. Braus, *Secretary*

The 1952–1953 series of meetings of the Hagerstown Section was opened with a dinner meeting on October 28 at the American Legion Club. Sixty-four members and guests were present. New officers installed at this time were: Chairman, H. C. Billings; Vice-Chairman, R. H. Ziegenfuss; Secretary-Treasurer, H. Weisenburger; Advisory Council, L. Fahnestock, E. R. Gelvin, W. Tydon, E. E. Morton, and R. D. Gilson; Representative to Area Nominating Committee, J. A. Neilson.

The reports of the outgoing committees and officers were read, after which Chairman Morton turned the meeting over to Allen Clopper, Chairman of the Program Committee. He introduced the speaker of the evening, Col. Arthur Fickel, Assistant Deputy for Development, Air Research and Development Command.

Colonel Fickel, whose talk included slides and motion pictures, began by projecting a map showing the location of the various research and development centers and describing the function of each. He spoke of the cooperation required among the various centers of the Air Research and Development Command and also told of the relationship with its customer, the Air Force. He commented upon the complexity of current and projected aircraft and compared the F-86 with the MIG aircraft currently in battle in Korea, showing



Pictured above is the Grumman F9F-6 COUGAR—
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that the results of this battle were much in favor of the F-86 in spite of its being outgunned. Colonel Fickel stated that the ratio of wins over losses was never worse than 5 to 1 and in June of 1952 was as high as 16 to 1 in favor of the F-86.

These results prove the superiority of balanced design where the overall product is maximized and that guns are not everything in a fighter. The speaker pointed out that the gunsight probably was the big difference because of the extremely small area of vulnerability (approximately 1 square yard) and the extremely high speeds of today's combat.

After a lively question and answer session, Colonel Fickel showed movies of the testing of the F-86 airplane through Phases I, II, III, and IV and of the firing of the Aero-bee rockets carrying mice and monkeys to extreme altitudes.

Montreal Section

B. J. Kaganov, *Secretary*

The first meeting of the year was a joint meeting sponsored by the I.A.S. Montreal Section, Institute of Aircraft Technicians, and Ottawa Aeronautical Society. It was held in Montreal on October 15.

The largest turnout of aircraft executives and technicians in one area of Canada came to the dinner meeting to hear William Lear, Chairman of the Board and Director of Research, Lear, Incorporated. Mr. Lear, manufacturer of automatic controls and holder of the Collier Trophy for great achievement in American aviation in 1949, spoke on automatic control of aircraft.

The main theme in Mr. Lear's paper was that a pilot is no longer necessary. While paying tribute to the part a pilot played in twentieth-century life, Mr. Lear said that the character had outlived his usefulness and that anything a pilot could do machines could do better.

A pilot slipped away, Mr. Lear said, because he was forced by modern aircraft to do the work of at least eight persons. This, the speaker said, brought about pilot error and the necessity of taking the load off a pilot's shoulders. The way to do this, Mr. Lear said, was easy—eliminate a pilot completely, and let a machine take over.

Mr. Lear said that with the pilot out of the way the West could get on with the job of building flying machines that needed no human guidance. Directed through impulses racing around the confines of a box known as an automatic pilot, these aircraft would go their appointed way untroubled by a pilot subject to such human frailties as fear, error, or desire to remain alive.

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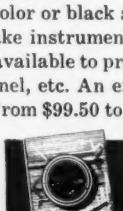

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The importance of this was to be prepared to make a stand should aggression come from Russia. He said that Russia has advanced guided missiles much further than the West has, and, if the West is to catch up, it had better get busy. His belief was based on that fact that Russia had captured many German guided missile sites and had rounded up the guided missile scientists at the end of World War II. Since then, this equipment and skilled manpower has been working for Russia.

Mr. Lear was not entirely pessimistic, however. He said that any one of a dozen U.S. or Canadian companies could, if given the contract, produce an equally good guided missile in 18 months.

New York Section

Charles Tilgner, Jr.
Secretary-Treasurer

The opening gun of the season was fired on October 28, 1952, at the plant of the Grumman Aircraft Engineering Corporation. Preceded by cocktails and dinner, the confidential meeting was attended by over 400 security-cleared members and associates. A distinguished panel, consisting of Brig. Gen. Albert Boyd, U.S.A.F., Commanding General, W.A.D.C.; Alexander Kartveli, Vice-President and Chief Engineer, Republic Aviation Corporation; Robert J. Woods, Chief Design Engineer, Bell Aircraft Corporation; and John Stack, Assistant Chief of Research, Langley Aeronautical Laboratory, N.A.C.A., did an outstanding job in discussing "Flow Separation and Attendant Stability Problems on Thin-Straight, Swept and Delta Wings."

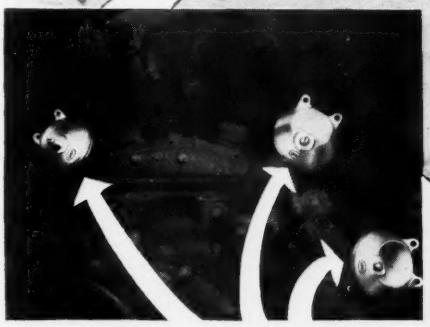
The meeting opened with a welcome from Robert L. Hall, Chief Engineer of Grumman, who then introduced C. E. Pappas, Chairman of the meeting. General Boyd spoke first, with a general review of the subject, followed by Mr. Kartveli who gave a thorough presentation of some flight results at Republic. Mr. Woods recounted Bell's experiences with the various research airplanes and displayed rare humor in his commentary on a movie of X-5 flights. Mr. Stack explained some of the phenomena encountered in transonic flight and gave a short preview of recent advances.

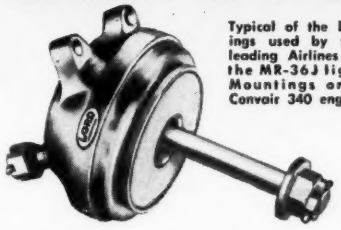
This meeting came close to establishing a new high in attendance, physical arrangements, and quality of technical material discussed. Orchids are due the committee of the evening.

St. Louis Section

Robert A. Killoren, *Secretary*

The annual election meeting of the St. Louis Section was held at the St. Louis





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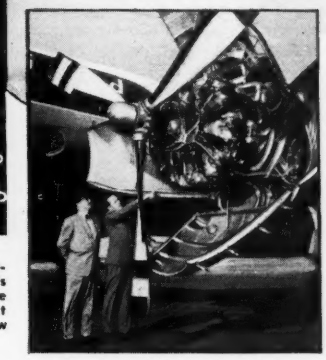

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Engineers Club on October 14. The new officers for the 1952–1953 period were elected unanimously in agreement with the report of the Nominating Committee.

The new officers are: Vernon Outman, McDonnell Aircraft Corporation, Chairman; Arthur Lowell, also of McDonnell Aircraft, Vice-Chairman; Allan McCoy, Sverdrup and Parcel, Inc., Secretary; and C. Donald Lundergan, Parks College, Saint Louis University, Treasurer.

The members of the Advisory Board are: Don Berlin, McDonnell Aircraft; Carl Wenzinger, Sverdrup and Parcel, Inc.; Niels C. Beck, Parks College; Will Wells, George E. Wells Company; and Charles Wood, McDonnell Aircraft.

Following the business meeting, a film was shown, which portrayed the *History and Progress of Jet Engine Development.* This concluded the formal portion of the meeting. About 60 members were present.

San Diego Section

Earl R. Hinz, *Secretary*

The monthly dinner meeting of the San Diego Section was held in the Marine Room of the San Diego Hotel on October 23. Guest speaker for the evening was Dr. Konrad J. Buettner, Department of Engineering, University of California, Los Angeles. Dr. Buettner's talk was literally "out of this world," since he discussed the several facets of "Space Medicine."

He noted that each new field of science to be explored has caused the invention of a new terminology. For instance, in space medicine the altitude layer, where the effects of the surrounding air on a flight vehicle and its occupants decline and cease to exist, has been termed the aeropause and is considered the functional border of space.

In the aeropause layer, the following conditions are known to occur: molecular oxygen ceases to exist above 10 miles; ozone exists from 10–30 miles; blood boils at 12 miles; cosmic particles are absorbed in the 13–23 mile range; aerodynamic lift becomes negligible at 50 miles; daylight ceases from 60–90 miles; the majority of meteors burn out in the 65–90 mile range; there is no thermal interaction beyond 100 miles; and aerodynamic drag vanishes at 120 miles. This summary of what to expect in the aeropause was aptly illustrated with slides.

Dr. Buettner then expanded in detail on the individual problems of manned flight in the aeropause. Outer space is not a void as commonly believed but is a region filled with solar protons, meteors, and cosmic particles. Protection from solar protons may be afforded by rubber suits or the space craft's shell. Collision with a large-size meteor is held less likely than the risk of an automobile accident in mid-town traffic, but meteor dust on the other hand is dense and may cause severe erosion of optical ports which will interfere with navigation. The seriousness of cosmic radiation and protection from it is not well established yet.

Heating of the space craft by air friction and solar radiation will require heat-resistant structural materials, efficient insulation, and reflective finishes. The reflective finish must have the added property of resisting erosion by meteor dust.

Gravity is not absent in the aeropause, but centrifugal forces will provide weightlessness for extended periods of time which necessitates intensive study of zero-gravity effects on the human body. Present knowledge indicates that the lack of gravity will affect the human spatial-orientation system, resulting in a feeling akin to seasickness. Forced ventilation will of necessity replace thermal convection that is absent in a gravitationless field.

SEATTLE SECTION MEETING

Otto E. Kirchner (F.), Director of Operational Engineering, American Airlines, addressing the Seattle Section of the Institute at the October 15, 1952, meeting. At the speakers' table, from left to right, are: George C. Martin, Chief Project Engineer, Boeing; Capt. Darrell Cole (partially obscured), B-52 Representative, S.A.C.; Edward C. Wells (A.F.), Vice-President, Engineering, Boeing; Wellwood E. Beall (F.), I.A.S. President and Senior Vice-President, Boeing; Mr. Kirchner; Lt. Col. Guy Townsend, B-52 Flight Test Representative, A.R.D.C.; Darrell B. Martin (A.F.), Chairman of the Seattle Section; Col. Austin Davis, Air Regional Representative, W.A.P.D., and Boeing A.F.P.R.; and Lysle A. Wood (A.F.), Boeing Chief Engineer.

Seattle Section

R. D. Fitzsimmons, *Secretary*

Approximately 125 members and guests enjoyed a technical session, preceded by cocktails and dinner, winding up the 1951–1952 meetings under the existing officers. Section Chairman D. B. Martin presented Girvis E. Ledbetter with a gift in appreciation of his contributions to the chapter as Program Chairman during the past year.

I.A.S. President Wellwood E. Beall then introduced Otto E. Kirchner, Director of Operational Engineering for American Airlines, Inc., who presented an extremely interesting paper entitled "Explosive Decompression." Mr. Kirchner supplemented his presentation with some excellent slides that gave mute evidence of the tremendous forces associated with explosive decompression. By tracing the history of pressurized cabins through today's aircraft, Mr. Kirchner was able to speculate on the aircraft of tomorrow and point out some of the problems that will probably arise. The higher speeds and greater passenger capacity of these new transports require that even greater efforts be made to keep the standards high. Bad publicity can be overcome by time alone, not by passenger-miles per year which mean nothing to the prospective customer. Mr. Kirchner praised highly the ability of present airplanes to withstand tremendous damage while retaining their ability to fly.

A movie followed which pointed out how critical certain items can be for passenger safety under explosive decompression. Among them are: seat location with respect to the window; inward, as well as fore and aft, pressure differential; size of window; and size of hole for air escapement. In addition to the movie, J. E. Barfoot commented

on passenger reactions due to explosive decompression at altitudes from 25,000–50,000 ft.

Texas Section

Charles L. Seacord, Jr., *Secretary*

On September 29, the results of a mail balloting for officers of the Texas Section were announced. The results are as follows: Chairman, W. A. Clegern; Vice-Chairman, D. G. Andreoli; Secretary, H. F. Marx; and Treasurer, A. Beverage.

The new officers assumed their duties on last October 1.

Washington Section

Paul J. Burr, *Secretary*

The 1952–1953 program of the Washington Section was opened with the October 7 meeting held as usual in the National Museum Auditorium. This meeting, attended by 284 persons, was devoted to the subject, "What Price Complexity?" This, of course, refers to the complexity of present and planned aircraft and the cost of this complexity in terms of airplane performance and budgets.

The Honorary Chairman was Lt. Gen. Lawrence C. Craigie, U.S.A.F., Deputy Chief of Staff—Development, Headquarters, U.S.A.F., and papers were presented by Ivan H. Driggs, Director, Research Division, Bureau of Aeronautics, U.S.N.; Col. B. A. Schriever, U.S.A.F., Assistant for Development Planning, D.C.S.—Development, U.S.A.F.; and E. H. Heinemann, Chief Engineer, El Segundo Plant, Douglas Aircraft Company. A premeeting dinner with 61 in attendance had been held at the Hotel Burlington.

Section Chairman J. H. Sidebottom opened the meeting with a welcome to all members and guests and an introduction to the Section officers and committee chairman, after which he introduced Wellwood E. Beall, I.A.S. President who was a guest at this meeting, to greet the Section. Mr. Beall spoke briefly on the I.A.S. theme for the year —increased attention to student activity. He outlined the progress already being made throughout the Institute and cited the Los Angeles Section for its activity in going into the high schools to interest more boys in engineering.

General Craigie was then introduced as Honorary Chairman. Apropos of aircraft complexity, he pointed out that much of it is caused by the more intricate tasks that the aircraft are required to perform. He also made a plea for a lessening of pressure on administrators of development programs. Thereby, more seasoned and experienced guidance would be available to avoid some of the complexity.

The papers delivered by the three speakers were well integrated to cover the subject of the evening. Mr. Diggs spoke of the disturbing upward trend in airplane gross weights and emphasized the benefits to be derived from the selection of optimum powers and structural weights to meet specific problems; Colonel Schriever pointed out the responsibilities of management; and Mr. Heinemann showed the effect on cost (and hence of aircraft to be purchased with a given sum) of unnecessary weight and complexity.

An interesting discussion period followed which indicated the following: (1) Attention to the airplane as a complete weapon system will reduce complexity and weight. (2) A greater range of powers available and a greater number of powers to select from would reduce aircraft gross weight. (3) Power-plant weights can and must be reduced. (4) Design responsibility by aircraft contractors for component systems for specific airplanes rather than the collection of many Government-furnished-equipment items within an airplane would result in reduced weight and complexity. (5) More attention to detail design by supervision would pay off. Most of our experienced aircraft engineers are engaged full time in administration.

In his talk, Mr. Driggs referred to his papers of the last few years wherein he has used a generalized approach to illustrate causes and corrections of the upward trend of airplane gross weights. He then outlined a more specific process of study for consideration. Four airplanes, designed to meet a specific problem, are required to have the same performance as follows: high speed at 35,500 ft., $M = 1.2$; combat radius, 400 nautical miles; load factor (limit), 6.0; and military load, 2,163 lbs.

Assumed specific power plants were chosen to fit these four specific studies and other designs interpolated between them, thus arriving at a number of possible designs. It was shown that only two of the aircraft with two specific (assumed) power plants with afterburning would meet the problem established. It was shown that a reduction in the military load of 350 lbs. could save nearly 22 times that amount in overall weight. Mr. Driggs also showed that an improved engine design (lighter in weight and better S.F.C.) should enable a twin-engine (4,000 lbs. thrust each) airplane to be a much better solution than a larger single-engined plus afterburner design. Mr. Driggs concluded that the effects of relatively small increases in design weight become magnified by the fact that an infinite series of power plants is not available, and, consequently, large changes in combat weight may result if we must go from one jet size to another to carry the relatively small increment of military load.

Colonel Schriever discussed the results of his studies over the past several months on organization for simplification of aircraft weapons systems. He outlined the necessary integration of engineering and management controls to telescope the time required to bring aircraft to combat-ready condition. Colonel Schriever showed slides depicting the new organization of the Air Force for the development of aircraft. This organization provides for specific responsibility for weapons-system control. Colonel Schriever's paper gave the impression that the Air Force believes that we cannot perform today's missions with simple aircraft but that we must design those complex machines with the weapons-system concept having overriding authority. He contended that reduction in weight may be obtainable with the required complexity if control over systems is maintained.

Mr. Heinemann entitled his paper "Aircraft Weight and Cost Can be Reduced." In this paper and with slides, the upward trend of weight and cost of aircraft was traced and compared with increased aircraft speeds. For example, Mr. Heinemann pointed out that $V_{max.}$ at present has only doubled over $V_{max.}$ in 1925, whereas the gross weight of military aircraft has increased 10 to 20 times. He cited that in 1930, $100,000,000 would buy over 1,100 fighter airplanes and that in 1950 such a fund would buy only 100 airplanes.

Mr. Heinemann's paper is published in full on pages 20–23 of this issue.

Student Branches

Academy of Aeronautics, Inc.

Frederick Berger
Corresponding Secretary

The three meetings herein reported were presided over by Branch Chairman Sherman Martin. At the October 2 meeting, which 26 members attended, the current business agenda was discussed, and the travelog *Wings to Hawaii* was shown.

▶ On October 15, 39 members met to discuss plans for a field trip to the N.A.C.A. laboratories at Langley Field, Va., which took place on October 31. The highlights of this trip, in which 35

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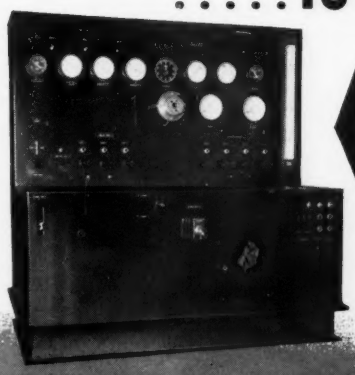

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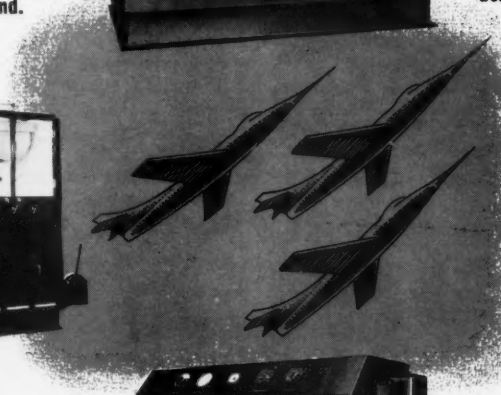

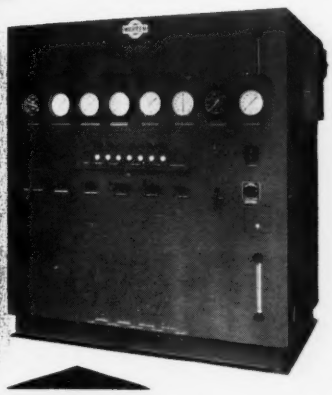

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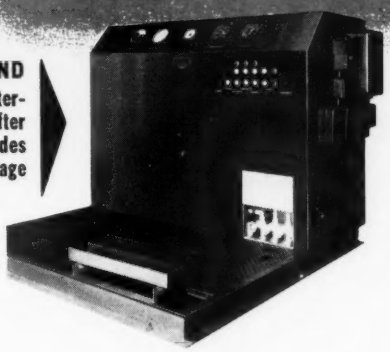

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members took part, were inspection of several subsonic and supersonic wind tunnels and visits to sheet-metal and machine shops, the Pilotless Aircraft Research Division, and the Flight Research Division.

▶ Two films were shown at the meeting on October 31; *The Air Force Voodoo*, an action report of the F-88 twin-engined fighter bomber, and *Airplanes—Their Metals, Fuels, and Lubricants*. The latter film shows how mines, oil fields, and maintenance shops are united into a successful air-line transport operation. This meeting was attended by 41 members.

▶ The Academy of Aeronautics Branch organized a field trip to the Republic Aviation Corporation plant at Farmingdale, Long Island, N.Y., and the Annual Fall Dance held at the Academy on December 6, which the Branch co-sponsored.

The Aeronautical University, Inc.

Chairman Lyman Welliver called the meeting of October 9 to order with 22 persons present. He discussed the advantages of being a student member and the attending requirements. The three films that were shown at the meeting were entitled *Basic Hydraulics*, *Basic Electricity as Applied to the Airplane Electric Control System*, and *How to Weld Aluminum*.

▶ With 21 students in attendance at the October 23 meeting, three films were shown. Two of them on drag and thrust are parts two and three, respectively, of a six-part Shell Oil Company film entitled *How An Airplane Flies*. The third film, *The Wonder Jet*, was obtained from the British Information Services and showed the history of the jet engine and the improvement of the present jet engines over the first one. Chairman Welliver presided.

Agricultural and Mechanical College of Texas

Elections were held at the September 24 meeting for the offices of Vice-Chairman and Secretary-Treasurer. Wayne Sabo was elected Vice-Chairman, and Theodore C. Nark became Secretary-Treasurer. Chairman Arthur P. Goldberg presided; 25 aeronautical engineering students were present.

Two films, *Fighter Action over Western Europe* and *Why Korea*, were shown at the October 15 meeting. Chairman Goldberg presided, and 46 students were in attendance.

Cal-Aero Technical Institute

Don Nakashima, *Secretary*

Forty-five members of the Cal-Aero Student Branch attended a tour of the California Institute of Technology Cooperative Wind Tunnel in Pasadena, Calif., on October 7. A special feature of the program was the lecture given by members of the wind-tunnel staff describing the important features of the tunnel, its construction, maintenance, and operation.

Mississippi State College

Thomas C. Pope
Corresponding Secretary

The Mississippi State College Branch held its second meeting of this semester on October 7. After reports were made from the various committees, Chairman A. A. Backstrom introduced the guest speaker, Bruce Carmichael, of the Mississippi State College Research Station. Mr. Carmichael spoke on "The Light Airplane of Today," indicating the improvements being made and what could be expected in the future. After a brief discussion period, the meeting was adjourned.

▶ Ray Parker, of the Mississippi State College Research Station, addressed the October 21 meeting on "The Development of the Tiny Mite." After the talk, Mr. Parker showed colored slides of the "Tiny Mite."

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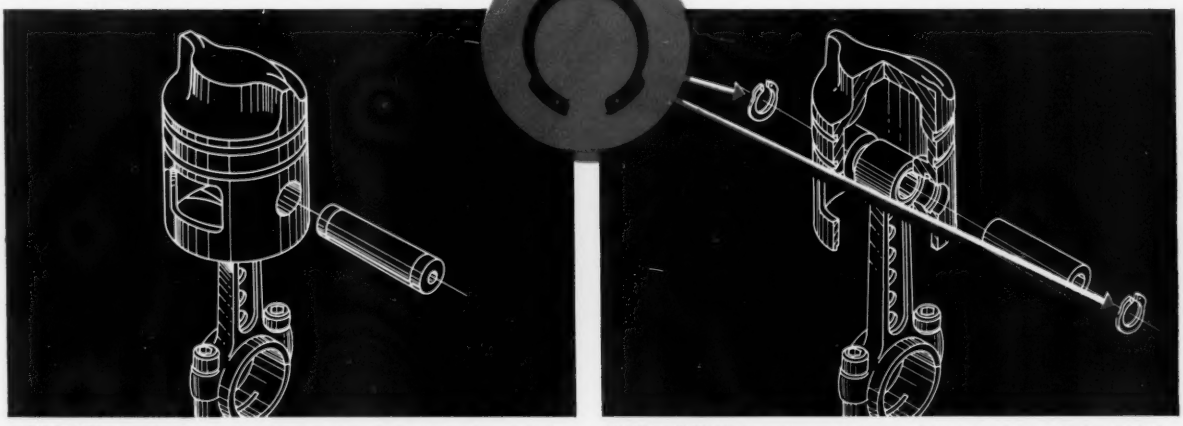

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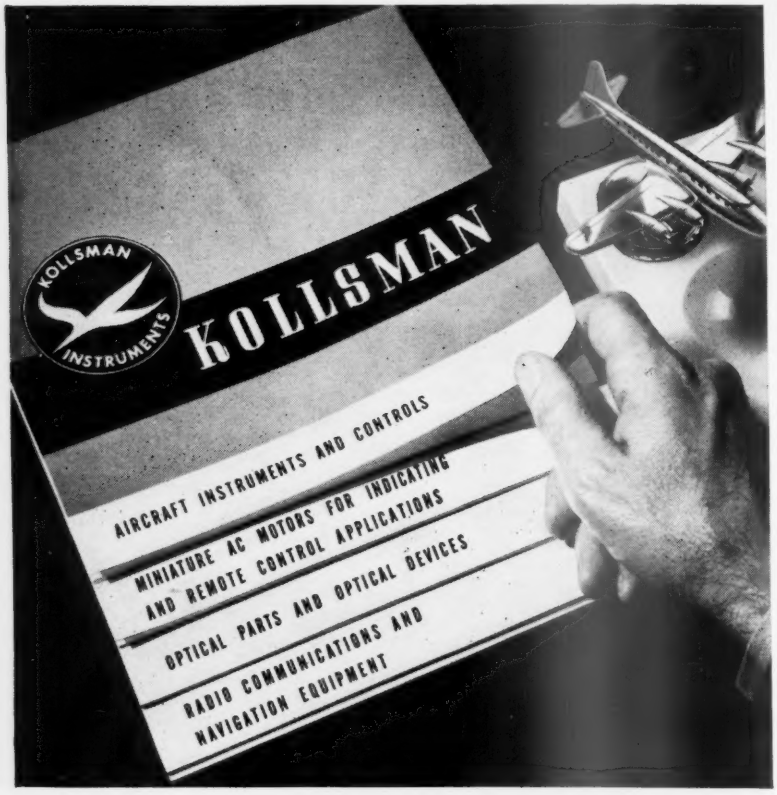

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▶ At the November 4 meeting, the guest speaker was Prof. Charles B. Cliett, of the Aeronautical Engineering Department. Professor Cliett's subject was "Perforated Structures," in which he covered the tests he had run, observations he had made, and conclusions he had reached. A short question period followed.

The Pennsylvania State College

Frank A. Leader
Secretary-Treasurer

The opening meeting of The Pennsylvania State College Student Branch was held on the Penn State campus. The Chairman, Max Schuster, welcomed about 60 students, the majority of whom were freshmen, and then proceeded to outline the ideals and principles of the I.A.S.

In this discussion, Max Schuster indicated how the functions of our local chapter have been rather hampered by lack of funds. The point was then raised and passed to double our present dues making them $2.00 per year (two semesters).

Our Faculty Advisor, Mr. Fox, was then introduced to the group. He briefly pointed out some of the opportunities afforded by the local chapter.

John Gaul gave a brief report on the Engineering Student Council and asked for a straw vote on whether we would support the Engineering Open House next spring by each member devoting some time to it. There was a good showing of hands.

The meeting was then adjourned and refreshments served.

Purdue University

On October 21, Dr. M. U. Clauser, Head of Purdue's School of Aeronautics, gave an illustrated talk on "Airplanes Displayed at the Farnborough Air Show." Chairman S. M. Johnson presided; 25 students were present.

Syracuse University

Charles E. Rogers, *Secretary*

The first meeting of the 1952–1953 school year of the Syracuse University Student Branch was called to order on October 1 by Chairman Robert Mack with 14 members and the Faculty Adviser, Joseph Cady, present.

The meeting began with a report from The Robert Ostrander Memorial Plaque Committee. All bills have been paid on the plaque, which was presented to the members for inspection. Plans for showing it to the former member's parents and for the presentation ceremonies were discussed.

During the business meeting, committees for the forthcoming year were selected. They are as follows: Library Committee—Edward Phillips, William Kelly, Fred Boenig; Program Committee—Joseph Cady, David Birdseye, Fred Boenig; Membership Committee—Robert Mack. Because of the accepted resignation of William Kelly as Secretary, Charles Rogers was elected Secretary to fill the vacancy.

An informative talk was given by Joseph Cady on the new engineering building at Syracuse University which is to be located on the main campus. The aeronautical department of the building, which is to be ready by fall of 1953, was the main concern of all present. The department reportedly will have four test cells, three wind tunnels—one of which will be of the supersonic type—and one water table. The rest of the meeting consisted of questions pertaining to what would be done with much of the equipment in the old aeronautical building.

University of Alabama

Dr. Carl Sartain, Consultant for the Atomic Energy Commission, was the speaker at the October 14 meeting. His subject was "Nuclear Propulsion for Aircraft." In this talk, Dr. Sartain covered the unrestricted phases of the subject. Chairman Richard J. Berman presided; 36 students were present.

University of Colorado

Franz Nawrocki, *Secretary*

The first meeting of the fall semester was brought to order by Chairman Cloman D. Bogart on October 1 with 14 members present and 22 prospective members attending.

Following a business meeting, Capt. Dale Borgen, of the A.F.R.O.T.C., presented several slides showing the character of the Korean people and the bomb damage in Seoul. These were taken while Captain Borgen was serving as a B-26 night-fighter pilot. Following the slides, Captain Borgen held a discussion period for the group.

University of Illinois

On October 15, the first meeting of the fall semester was opened by Chairman Gordon D. Booz with 100 persons present. After the business of the meeting was discussed, two films were shown. The first one, *Guided Missiles*, classified missiles according to (a) their propulsion units and (b) their guidance systems. The second film, *The V-2 Rocket*, showed the methods used in preparing rockets for testing, the actual blasting off of several missiles, and the methods used for recovering recording equipment.

The University of Oklahoma

Chairman Lawrence Fred Smith called the October 23 meeting to order with 22 students present. After the showing of a film on *Attitude Gyro*, Student Member Jack S. Webb spoke on "Charles Lindbergh's Trans-Atlantic Flight."

University of Texas

Twenty-six members and prospective members were present at the September 25 meeting. Faculty members W. H. Shutts, J. W. Dalley, and Dr. M. J. Thompson attended the meeting, and each made a short address of welcome to the new members.

Felix W. Fenter was appointed temporary chairman of this first meeting of the semester, and an election of officers took place. The following persons were elected: Chairman, Felix W. Fenter; Vice-Chairman, Jack E. Fairchild; Secretary, James M. Cooksey; and Treasurer, Lawton Blalock. The Faculty Sponsor is W. H. Shutts.

A film, *Flutter of Elastic Models*, was shown.

▶A picnic was held at Claremont, Okla., on September 20 in order to acquaint the new students with the instructors and older students. Free airplane rides were given to all those who had joined the Student Branch during the preceding week. D. D. Funk gave a demonstration of crop dusting.

University of Tulsa

▶ On September 25, Chairman Edward H. Roberts led the meeting at which 23 students were present. Everett W. Garrison, Plant Liaison Engineer, Tulsa Plant of Douglas Aircraft Company, Inc., spoke on "Problems in Plant Liaison."

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Flugge-Lotz, I., Dr.-Ing., Research Assoc. & Lecturer, Stanford University.

MacLennan, Alexander M., B.Sc., Research Engr. "A," Lockheed Aircraft Corp.

Transferred to Associate Fellow Grade

Lurie, Harold, Ph.D., Head, Weapons Effectiveness Group, Aircraft Div., The RAND Corp.

Martin, Darrel B., B.S.Ae.E., Sr. Technical Rep., Military Programs (Sales Div.), Boeing Airplane Co. (Seattle).

Rodgers, Oliver E., M.S., Asst. Mgr. of Engrg., Westinghouse Electric Corp.

Sauers, William F., M.Sc., Customer Relations Mgr., Chase Aircraft Co., Inc.

Scherberg, Max G., Ph.D., Chief of Applied Mathematics, A.D.C., Wright-Patterson A.F.B.

Turner, M. Jonathan, M.Ae.E., Vibration Unit Chief, Boeing Airplane Co. (Seattle).

Woodhams, Ronald J. B., B.Sc., Chief Designer, Aircraft Div., Air Service Training, Ltd. (Southampton).

Elected to MEMBER Grade

Barber, Edwin G., Chief Draughtsman, Central Design Office, British Overseas Airways Corp.

Boshar, John, B.S.E., Design Specialist, Goodyear Aircraft Corp.

Cushing, William J., B.S., Comdr. & Special Proj. Officer, U.S.N., Wright-Patterson A.F.B.

Detweiler, James I., B.M.E., Research Group Engr., Lockheed Aircraft Corp.

Eckert, E. R. G., Dr. Habil, Prof. of Mech. Engrg., Institute of Technology, University of Minnesota.

Ford, Arthur R., M.S.M.E., Aero. Engr., N.A.D.C. (Johnsville).

Francis, Donald L., A.E., Chief of Data Analysis Group, Wind Tunnel Section, Jet Propulsion Lab., California Institute of Technology.

Gerry, David C., B.S. in Industrial Engrg., Aircraft Gas Turbine Specialist, General Electric Co. (Los Angeles).

Haverstick, S. Alexander, B.S. in E.E., Mgr., Marine & Aviation Engrg., Westinghouse Electric Corp.

Hezlep, Robert B., Jr., B.S., Struct. Group Engr., Hayes Aircraft Corp.

Hitchcock, Lester M., B.S. in Ae.E., Staff Engr.—Struct., Boeing Airplane Co.

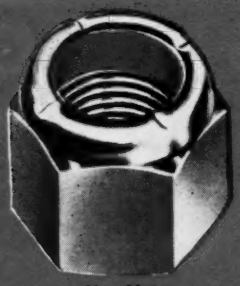
Hoch, John L., B.E., Prelim. Design Engr., AiResearch Mfg. Co.

Kawamura, Ryuma, Dr. Sc., Assoc. Prof., Member of the I.S.T., Institute of Science & Technology, University of Tokyo.

Mount, Joseph S., M.S. in M.E., Aerodynamicist (Thermodynamics), Proj. Leader, North American Aviation, Inc. (Los Angeles).

Neff, LeRoy W., B.S.E.E., Proj. Engr. (N.W. District Office), Sperry Gyroscope Co. Div., The Sperry Corp.

Phillips, Franklyn W., S.B., Chief, Aircraft Loads & Struct. Div., N.A.C.A. Hq., Washington, D.C.



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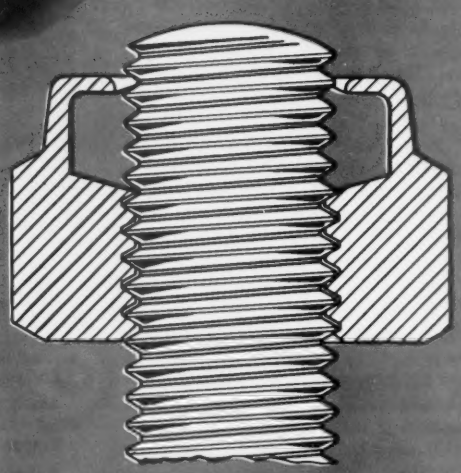

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Rutherford, Bruce J., B.S., Pres., Microwave Engineering Co.

St. John, Harry M., Jr., B.S. in A.E.-M.E., Systems Engr., Hamilton Standard Div., United Aircraft Corp.

Sheh, Kenneth, B. of Engrg., Aero. Engr., Canadian Pacific Airlines (Repairs), Ltd.

Spangenberg, Wesley, B.S., Mech. Engr. (Aerodynamic Instrumentation), GS-12, Research & Testing Lab., National Bureau of Standards (Washington, D.C.).

Tanck, Rudolf L., B.S.B.A., Group Leader—Weight Control, North American Aviation, Inc. (Columbus).

Ward, Elmer F., B.S., Chief Engr., Aerolab Development Co.

Wenzlau, William D., M.S.Ae.E., Applications Engr. (West Coast Office), Stratos Div., Fairchild Engine & Airplane Corp.

Williamson, C. Glen, B.S., Pres., Kellett Aircraft Corp.

Zarem, A. M., Ph.D., Dir., Los Angeles Div., Cons. Engr. on Research & Devel. Activities, Electronics, Stanford Research Institute.

Transferred to MEMBER Grade

Arkin, Shepard M., M.Sc. in Ae.E., Head, Guided Missiles Unit, Flying Qualities & Flight Test Section, Aerodynamics & Hydrodynamics Br., Design Elements Div., Bureau of Aeronautics, Dept. of the Navy.

Baker, Emmet E., Jr., Chief, Airborne Communications Branch, Directorate of Electronics, Hq., A.R.D.C. (Baltimore).

Bryson, Arthur E., Jr., Ph.D. in Aeronautics, Research Physicist, Hughes Aircraft Co.

Bursnall, William J., M. of Ae.E., Aero. Research Scientist—Aerodynamics III, Langley Aeronautical Lab., N.A.C.A.

Church, James D., B.S. in Ae.E., Aero. Research Scientist-Proj. Engr., Stability & Control Branch, Pilotless Aircraft Research Div., N.A.C.A., Langley A.F.B.

Corbett, Marshall J., B.S. in Ae.E., Power Plant Engr., Guided Missile Group, Grumman Aircraft Engineering Corp.

Crone, John L., Capt., U.S.A.F.; Research Liaison Engr., Airborne Electronic Equipment, Sandia Corp.

Dugundji, John, Sc.D. in Ae.E., Sr. Stress Analyst, Republic Aviation Corp.

Ferdman, Saul, M. of Ae.E., Struct. Engr., Struct. Flight Test Group, Grumman Aircraft Engineering Corp.

Forrette, Robert E., B.S.Ae.E., Aero. Research Scientist, Compressor & Turbine Div., Lewis Flight Propulsion Lab., N.A.C.A.

Garber, Theodore B., M.S. in Ae.E., Research Asst., Meteor Engrg. Div., Massachusetts Institute of Technology.

Gibler, David L., B.S. in Ae.E., Aircraft Designer "B," Douglas Aircraft Co., Inc. (El Segundo).

Gillespie, Robert W., B.S. in Ae.E., Cockpit Arrangement Group Leader, Northrop Aircraft, Inc.

Hartman, Creighton D., M.S. in Ae.E., Aerodynamicst "A," Radioplane Co.

Hedgepeth, John M., B.Sc. in Ae.E., Head, Dynamics & Aeroelasticity Section, N.A.C.A., Langley A.F.B.

Higman, John H., M. of Ae.E., Research Engr., Grumman Aircraft Engineering Corp.

Horney, Ernest E. J., B.A.Sc. in Ae.E., Proj. Engr., Fleet Manufacturing, Ltd.

Leo, Devere W., B.S. in Ae.E., Assoc. Research Engr. "A," Boeing Airplane Co. (Seattle).

Marshall, Edmund V., M.S. in Ae.E., Supvr., Design Analysis, Power Plant Analysis Group, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Mitchell, John C., B.S., Lt. Comdr., U.S.N.R.; Aviation Tech. Training Officer, N.A.S. (Minneapolis).

Mock, Wendell D., B.S.Ae.E., Stress Analyst "A," Struct. Section, Engrg. Dept., North American Aviation, Inc. (Los Angeles).

Murphy, James S., Ph.D., Assoc. Research Engr., Engrg. Research Institute, University of Michigan.

Pickford, Henry W., Jr., B.S., Member, Systems Devel. Group, Proj. Meteor, Massachusetts Institute of Technology.

Rodean, Howard C., M.Sc. in Ae.E., Power Plant Analyst "B," Power Plant Analysis Group, Chance Vought Aircraft Div., United Aircraft Corp.

Slone, Henry O., M.S., Aero. Research Scientist, Lewis Flight Propulsion Lab., N.A.C.A.

Snyder, Martin A., B. of Ae.E., Sr. Flight Test Engr., Bell Aircraft Corp.

Sohn, Robert L., M.S. in M.E., Research Aerodynamicist, Propulsion Research Corp. (Inglewood).

Sonnemann, George, M. of Ae.E., Asst. Research Engr., Dept. of Engrg. Mech., Engrg. Research Institute, University of Michigan.

Trapp, Albert E., M.S.Ae.E., Proj. Struct. Engr., Hiller Helicopters, Inc.

Witbeck, Norman C., M.A.E., Exec. Dir., Propulsion Panel, Research & Devel. Board (Pentagon).

Elected to Associate Member Grade

Moore, John D., Field Service Rep., North American Aviation, Inc.

Paddon, Albert, Foreman, Engine Test Inspection Dept., A. V. Roe Canada, Ltd.

Elected to Technical Member Grade

Baumeister, Philip W., B.S. (Physics), Jr. Engr.—Research, Flight Instrumentation Section, Lockheed Aircraft Corp.

Bolles, Jonothan, B.S., Aerodynamicist "B," Northrop Aircraft, Inc.

Brougham, Harold E., B.S.M.E., Stress Analyst, Devel. Section, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Bush, Powell D., Jr., M.A. in Physics, Admin. Asst.—Engrg., Lockheed Aircraft Corp. (Georgia).

Chaplin, Harvey R., Jr., B.M.E., Mechanical Engr., Aero. Div., Aeroballistic Research Dept., Naval Ordnance Lab. (White Oak).

Creel, Louis G., Jr., B.S. in C.E., Stress Analyst, Engrg. Dept., Devel. Group, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Friedlaender, Frank, B.S.M.E., Proj. Engr., Southern California Cooperative Wind Tunnel.

Gilbert, Donald D., B.S. in Education, Engrg. Training Instr., North American Aviation, Inc. (Columbus).

Golding, Thomas A., B.S., Jr. Engr.-Draftsman "A," Lockheed Aircraft Corp.

Infiorati, Mathew E., B.S.M.E., Jr. Engr. "A," Grumman Aircraft Engineering Corp.

LeMay, Dan B., B.S.M.E., Prelim. Analysis Engr., AiResearch Mfg. Co. Div., The Garrett Corp.

Morell, John D., B.S. in Ae.E., Aero. Engr. & Cpl. assigned to 9203 TSU-TC, Research & Devel. Station, U.S.A. (Ft. Eustis).

Myers, Samuel A., B.S., Asst. Engr. "A," Northrop Aircraft, Inc.

Naclerio, Albert P., A.A. in Ae.E., Struct. Draftsman, Fuselage Section, Grumman Aircraft Engineering Corp.

O'Massey, R. Conrad, Stress Engr., Lockheed Aircraft Corp.

Schierman, Robert H., B.S. in E.E., Exp. Flight Test Operations & Analysis Engr., Boeing Airplane Co. (Seattle).

Tearnen, John O., M.Sc., Aerodynamicist "A," Northrop Aircraft, Inc.

Vickers, Richard James, Jr. Engr.-Draftsman "A," Northrop Aircraft, Inc.

Whitmer, James E., B.Sc., Flight Test Engr. "B," Lockheed Aircraft Corp.

Transferred to Technical Member Grade

Andreoli, Alfred E., Engr., Fletcher Aviation Corp.

Asbjorn, Karlsen, Jr. Engr., Burns Aero Seat Co., Inc.

Bauserman, Charles R., B.M.E. (Aero.), Aerodynamicist, North American Aviation, Inc. (Downey).

Booth, Floyd W., B.S. in Ae.E., Engrg. Liaison Man, Douglas Aircraft Co., Inc. (Tulsa).

Bouvier, Arthur O., Jr., B.S., Capt., U.S.A.F.; Proj. Engr., A.D.C., Wright-Patterson A.F.B.

Byrne, John T., B. of Ae.E., Grad. Student, Aero. Engrg. Dept., Polytechnic Institute of Brooklyn.

Camara, John L., B.S.C.E., Capt., U.S.A.F.; Proj. Officer, A.D.C., Wright-Patterson A.F.B.

Campbell, William E., B.S., Draftsman "A," Enclosures & Doors Group, Douglas Aircraft Co., Inc. (Long Beach).

Carey, Thomas A., Aerodynamicist, McDonnell Aircraft Corp.

Castor, James J., Draftsman "A," Fletcher Aircraft Corp.

Churchill, Richard E., Engrg. Draftsman "A," Power Plant Section, Northrop Aircraft, Inc.

Coffey, Gerald E., B.S., Jr. Engr., Operations Analysis Group, Consolidated Vultee Aircraft Corp. (San Diego).

Collins, Thomas E., B. of Ae., Jr. Engr., Aerophysics Dept., Technical Design Section, Consolidated Vultee Aircraft Corp. (Ft. Worth).

Copeland, William C., Jr., B.S.M.E. (Aero.), Design Draftsman, Douglas Aircraft Co., Inc. (Long Beach).

Crum, James K., Jr., B.S.

Doebelin, Ernest O., B.S., Research Asst., Ohio State University.

Eberspacher, Warren A., B. of Ae. E., Asst. Proj. Engr., Missile Test Dept., N.A.M.T.C. (Pt. Mugu).

Englert, Richard H., Field Service Rep., Northrop Aircraft, Inc.

Fessenden, Thomas E., B. of Ae.E., Research Engr., Grumman Aircraft Engineering Corp.

Fuller, Paul N., B.S. in Ae.E.

Geckler, Raymond H., B.S. in Ae.E., Design Engr., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Gribble, Walter G., M.S. (Electronics), Capt. & Research Devel. & Design Officer, U.S.A.F.

Hill, Harry N., Test Engr., Northrop Aircraft, Inc.

Holmdahl, Myles, B.S., Jr. Engr., Boeing Airplane Co. (Wichita).

Jasen, Frank S., B.S., Capt., U.S.A.F.; Research & Devel. Administrator-Weapons System Engr., A.D.C., Wright-Patterson A.F.B.

Kaufman, Charles H., B.S. in Ae.E., Design Engr., Wind Tunnel Model Group, Chance Vought Aircraft Div., United Aircraft Corp.

Kies, John R., B.S. in Ae.E., Mathematician "A," Performance Group, Aerodynamics Section, Douglas Aircraft Co., Inc. (El Segundo).

Martinson, Raymond E., B.S. in Ae.E., Coordinator "B," F-89 Project Office, Northrop Aircraft, Inc.

McCloud, John L., III, M.S. in Ae.E., Aero. Research Scientist, 40- by 80-ft. Wind Tunnel, Ames Aeronautical Lab., N.A.C.A.

McKaig, William D., B.S., Jr. Engr.—Struct. Design, Chance Vought Aircraft Div., United Aircraft Corp.

Mello, John F., B.S. in Ae.E., Aerodynamicist "C," Stability & Control, McDonnell Aircraft Corp.

Minor, Charles B., B.S.M.E., Capt., U.S.A.F.; Engr., Armament Lab., A.D.C., Wright-Patterson A.F.B.

Muscha, Myron F., B.S.M.E., Jr. Engr.-Draftsman "B," Lockheed Aircraft Corp. (Burbank).

Newman, Charles J., B.S.M.E., A/1C, U.S.A.F.; Airborne Radio Mech., 76th Troop Carrier Sq., MIA (Miami).

Norton, Thomas P., B.S. in Ae.E., Aerodynamicist, McDonnell Aircraft Corp.

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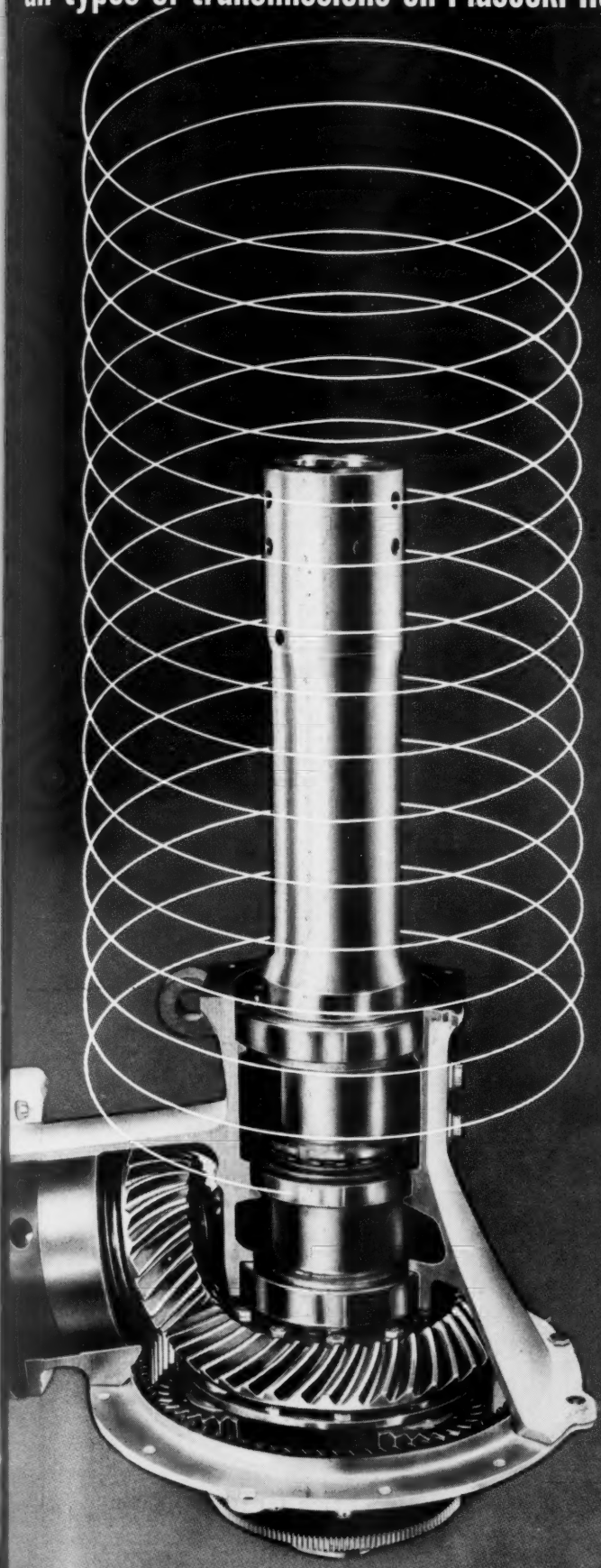

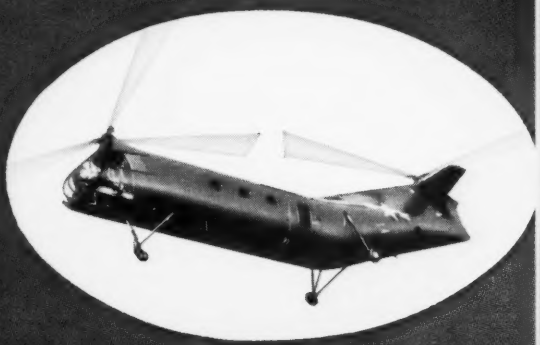

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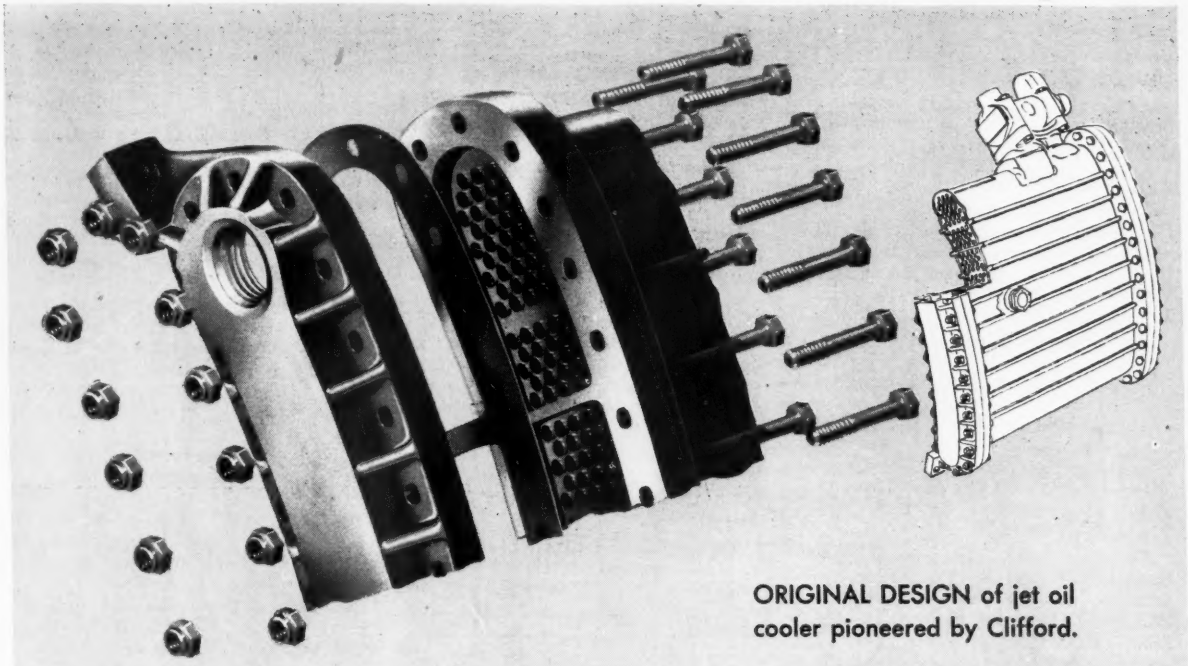

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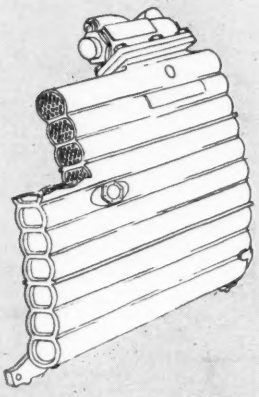

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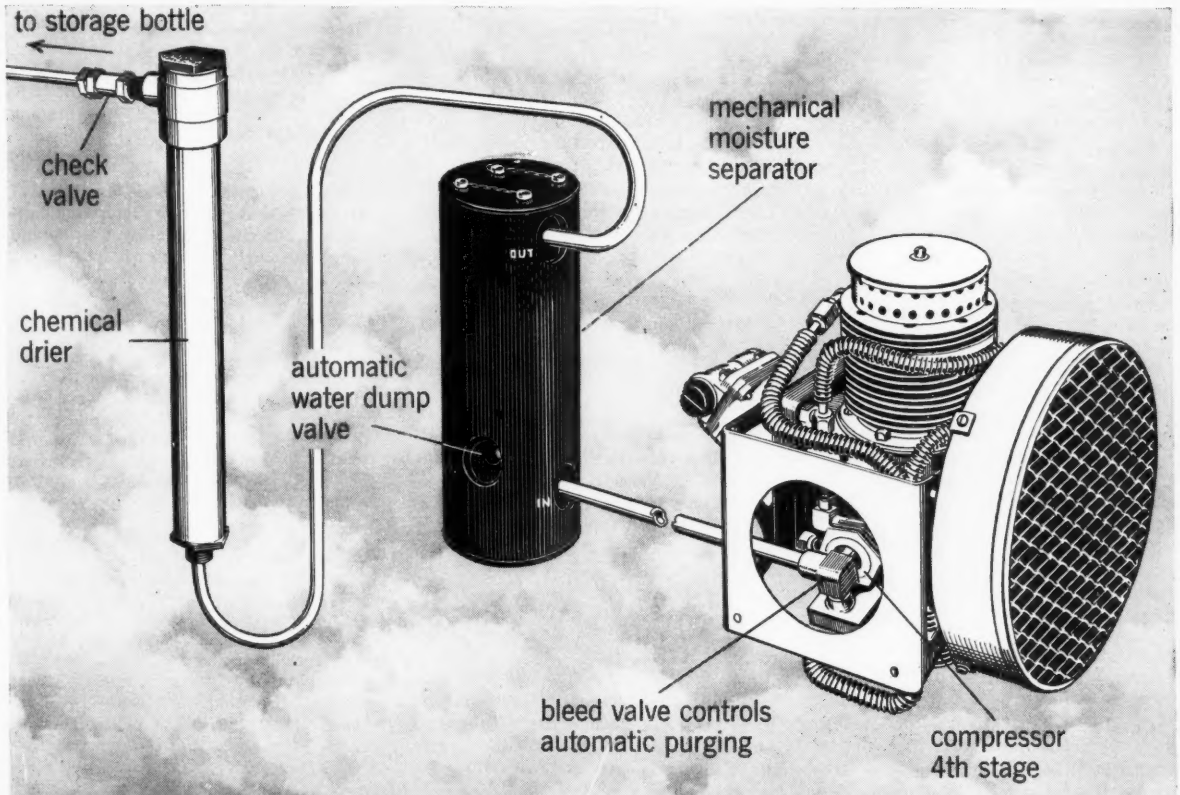

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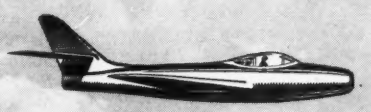

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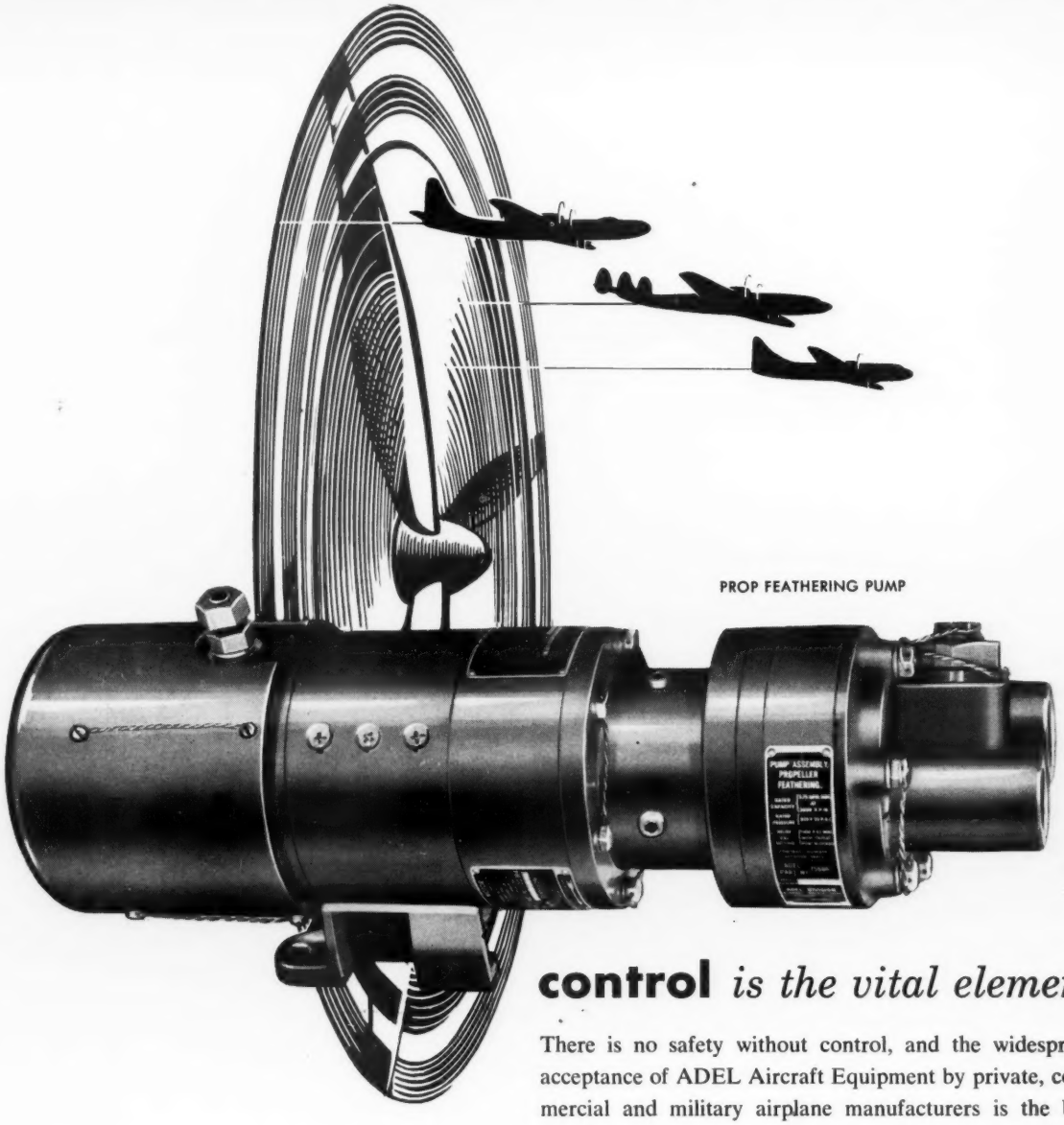

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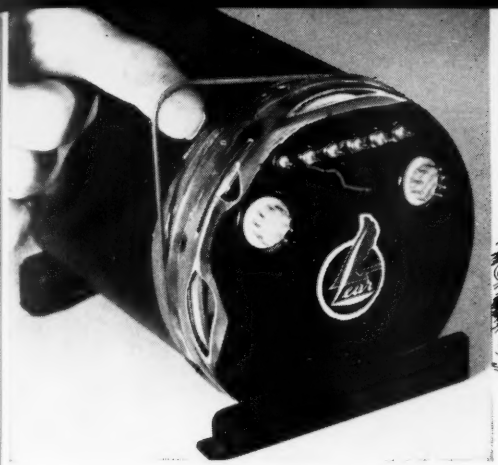

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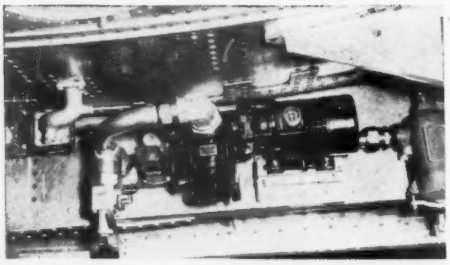

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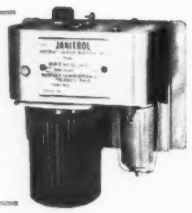

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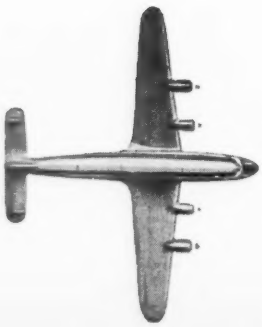

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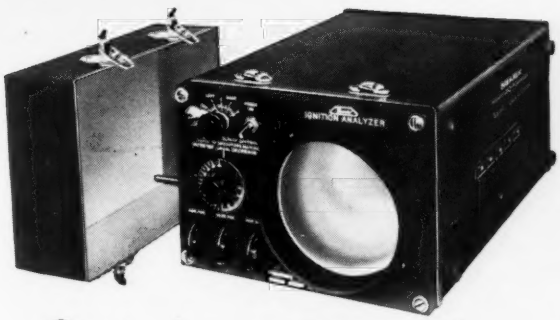

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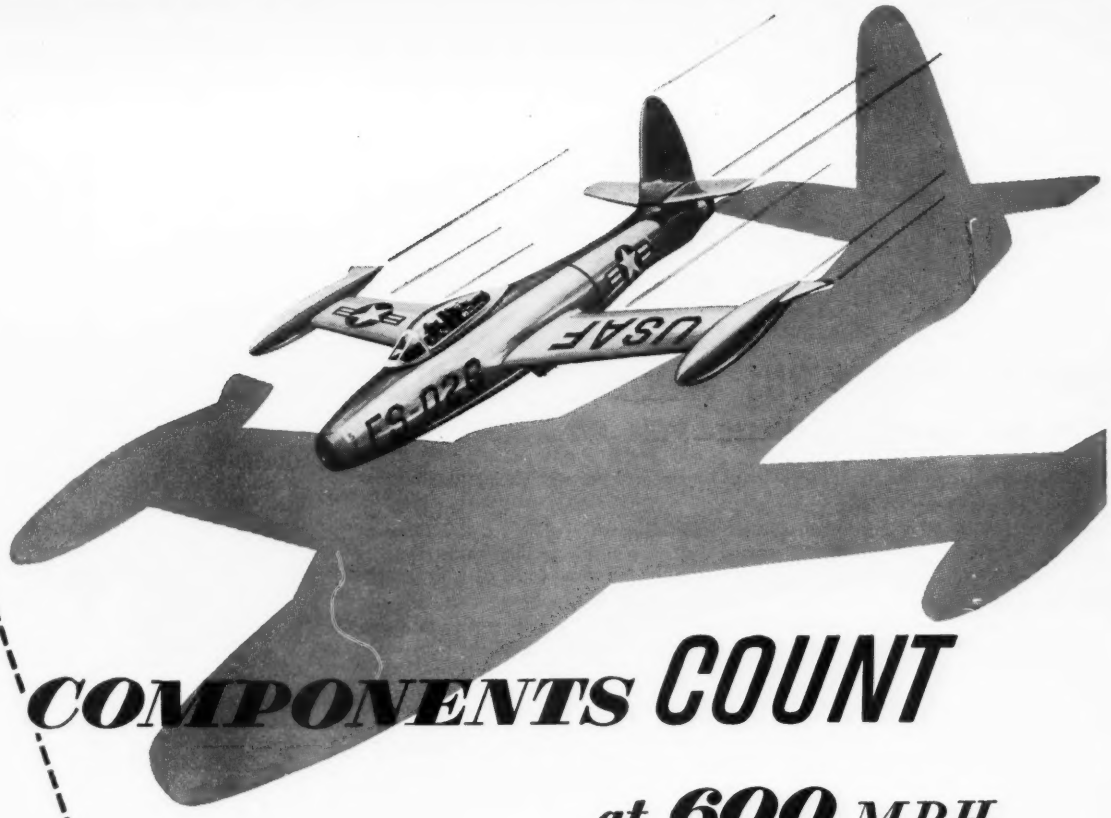

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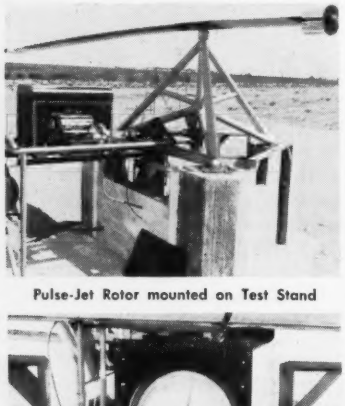

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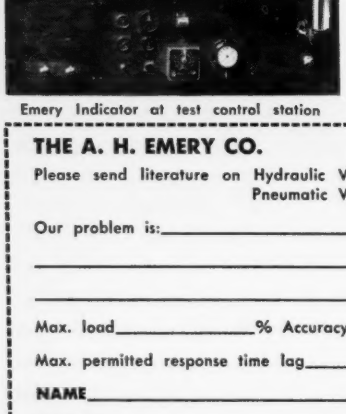

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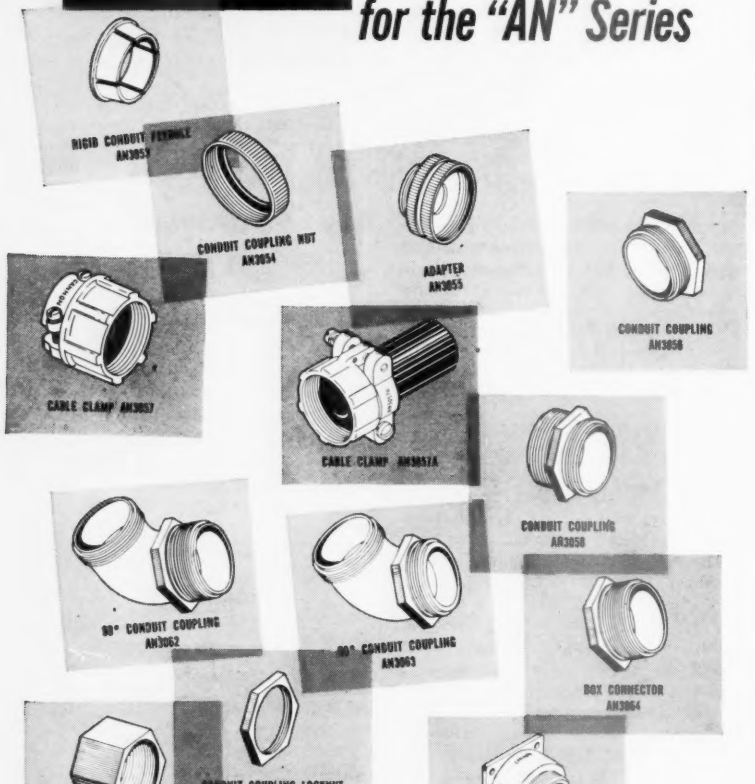

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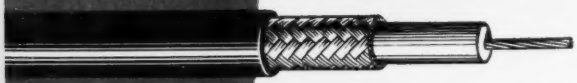

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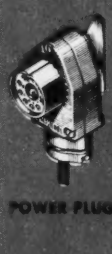

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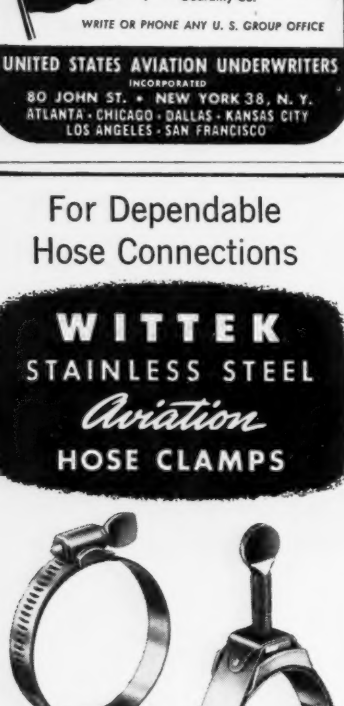

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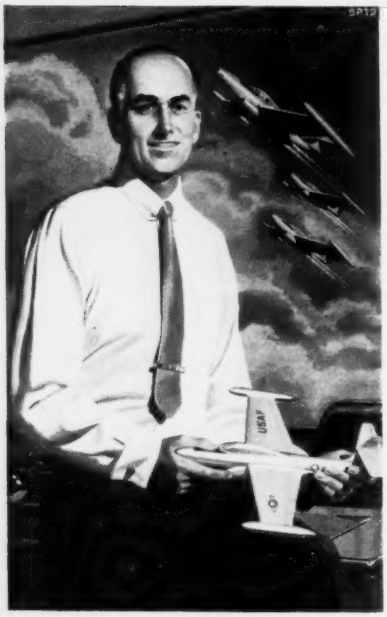

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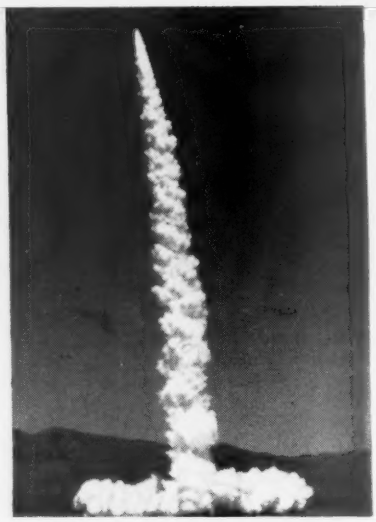

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Aerodynamic Characteristics of Three Deep-Step Planing-Tail Flying-Boat Hulls and a Transverse-Step Hull with Extended Afterbody. John M. Riebe and Rodger L. Naeseth. (*U.S., N.A.C.A., Research Memorandum Nos. L6J23a, L8I27,* 1946, 1948.) *U.S., N.A.C.A., Technical Note No. 2762,* August, 1952. 28 pp., illus. 8 references.

An Investigation into the Effect of Forced and Natural Afterbody Ventilation on the Hydrodynamic Characteristics of a Small Flying Boat (Saro 37) with a 1:20 Fairing over the Main Step. J. A. Hamilton. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2714,* 1951 (November, 1947). 18 pp., illus. 1 reference. British Information Services, New York. $1.25.

Tank Tests on a Hull with the Main Step Faired in Planform and Elevation. D. I. T. P. Llewelyn-Davies. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2708,* 1952 (May, 1945). 36 pp., illus. 12 references. British Information Services, New York. $2.10.

New Hull Forms for Flying Boat Design. Robert McLarren. *Aero Digest,* Vol. 65, No. 1, July, 1952, pp. 68–70, 72, 74, 76–78, 80, 82, 84, 86, 87, 89–92, illus. 37 references.

America is Developing Flying-Boats. John W. R. Taylor. *Air Pictorial,* Vol. 14, No. 9, September, 1952, pp. 260–262, illus.

A Theoretical Examination of the Effect of Deadrise on Wetted Area and Associated Mass in Seaplane-Water Impacts. R. J. Monaghan. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2681,* 1952 (March, 1949). 16 pp., illus. 6 references. British Information Services, New York. $1.15.

Theoretical Analysis of Hydrodynamic Impact of a Prismatic Float Having Freedom in Trim. Robert W. Miller. *U.S., N.A.C.A., Technical Note No. 2698,* June, 1952. 31 pp., illus. 10 references.

A Review of the Essentials of Impact Force Theories for Seaplanes and Suggestions for Approximate Design Formulae. R. J. Monaghan. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2720,* 1952 (November, 1947). 27 pp., illus. 17 references British Information Services, New York $1.60.

Navy Patrol; Land-Based or Seaplane? Norvelle W. Sharpe. *Aero Digest,* Vol. 65, No. 1, July, 1952, pp. 17–23, illus.

The Planing Characteristics of a Surface Having a Basic Angle of Dead Rise of 20° and Horizontal Chine Flare. Walter J. Kapryan and Irving Weinstein. *U.S., N.A.C.A., Technical Note No. 2804,* October, 1952. 42 pp., illus. 11 references.

A Method for Determining the Water Stability of a Seaplane in Take-Off and Landing. H. G. White and A. G. Smith. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2719,* 1952 (May, 1943). 12 pp., illus. 4 references. British Information Services, New York. $0.90.

Wind Tunnels & Research Facilities

Fatigue-Testing Laboratory; Expansion by the British Welding Research Association at Abington. *Aircraft Production,* Vol. 14, No. 166, August, 1952, p. 288, illus.

Dousing the Decibels; A Practical Solution of Gas-Turbine Testbed Silencing Problems. *Flight,* Vol. 62, No. 2276, September 5, 1952, pp. 337, 338, illus. Horace W. Cullom's Detuner.

Engine Test-Stand Silencing (at Dallas Airmotive, Inc.). *Flight Magazine,* Vol. 38, No. 1, July, 1952, p. 23, illus.

Testing Naval Ordnance; Task of the Research and Development Center at Inyokern. W. V. R. Vieweg. *Ordnance,* Vol. 37, No. 193, July–August, 1952, pp. 70–73, illus. Includes rocket, guided missile, and aviation fire-control research.

Use of Fences to Increase Uniformity of Boundary Layer on Side Walls of Supersonic Wind Tunnels. Rudolph C. Haefeli. *U.S., N.A.C.A., Research Memorandum No. E52E19,* July 16, 1952. 15 pp., illus. 9 references.

Design of a New Balance System for the Kirsten (8′ × 12′) Wind Tunnel. Louis B. Gratzer. *The Trend in Engineering,* Vol. 4, No. 3, July, 1952, pp. 13–16, illus. 4 references.

The New Saab Jet Wind Tunnel. Frid Wänström. *Saab Sonics,* No. 17, 1952, pp. 20–24, illus. Description and underlying theory; results.

A Theory and Method for Applying Interferometry to the Measurement of Certain Two-Dimensional Gaseous Density Fields. Walton L. Howes and Donald R. Buchele. *U.S., N.A.C.A., Technical Note No. 2693,* April, 1952. 46 pp., illus. 8 references.

True Airspeed Measurement by Ionization-Tracer Technique. Bemrose Boyd, Robert G. Dorsch, and George H. Brodie. *U.S., N.A.C.A., Research Memorandum No. E52C31,* July 21, 1952. 37 pp., illus. 10 references.

Windless Wind Tunnel. *Automotive Industries,* Vol. 107, No. 3, August 1, 1952, p. 47, illus. Electronic flight simulation equipment to test Air Force's Northrop Scorpion.

Use of Choked Nozzle Technique and Exhaust Jet Diffuser for Extending Operable Range of Jet-Engine Research Facilities. John H. Povolny. *U.S., N.A.C.A., Research Memorandum No. E52E12,* July 22, 1952. 17 pp., illus. 2 references.

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Aeronautical Reviews — BOOKS

Book Notes

EQUIPMENT

ELECTRIC

Direct-Current Machinery. Charles S. Siskind. New York, McGraw-Hill Book Company, Inc., 1952. 319 pp. illus., diagrs., figs. $6.00.

This book is intended for use in a one-semester course for students of electrical engineering. A background of elementary principles of electric and magnetic circuits is assumed. Derived equations are employed throughout the text to stress the importance of quantitative analyses as well as to augment discussions. Graphic methods help to illustrate the subject matter. The text progresses through the fundamental theories of generators and motor operation, the uses of auxiliary and control equipment, numerous constructions and applications of d-c machines and devices, and the development of many of the special machines now widely used. The author is Assistant Professor of Electrical Engineering, Purdue University.

FUELS

Aviation Fuels and Their Effects on Engine Performance. (Navaer-06-5-501, U.S.A.F. T.O. No. 06-5-4.) New York Ethyl Corporation, 1951. 145 pp., illus., diagrs.

The book has been prepared to provide information concerning the more important properties of aviation fuel and covers in particular those properties that are of most interest to the user of the fuel. The discussion deals largely with the effects of fuel properties on engine performance. The effects of engine design and engine operation conditions on fuel behavior are also covered. The discussion concerns only aviation fuels and aviation engines, except in the rare cases where other types of fuels and engines are specifically mentioned. The text is intended for those concerned with engine operation, design, and development, and not for those concerned with other phases of the aviation fuel problem.

MATERIALS

Fatigue and Fracture of Metals. A Symposium Held at the Massachusetts Institute of Technology, June 19–22, 1950. Edited by William M. Murray. Cambridge, Mass., The Technology Press, Massachusetts Institute of Technology; New York, John Wiley & Sons, Inc., 1952. 313 pp., illus., diagrs., figs. $6.00.

Contents: General Survey of the Problem of Fatigue and Fracture, M. Gensamer. The Fatigue Problem in Airplane Structures, H. L. Dryden, R. V. Rhode, and P. Kuhn. Brittle Fracture and Fatigue in Ships, F. Jonassen. Brittle Fracture and Fatigue in Machinery, R. E. Peterson. Internal Stresses and Fatigue, O. J. Horger and H. R. Neifert. Designing for Fatigue, R. L. Templin. Fundamentals of Brittle Behavior in Metals, E. Orowan. Experimental Study on Temper Brittleness of Slightly Alloyed Carbon Steel, P. A. Jacquet and A. R. Weill. The Statistical Aspect of Fatigue Failures and Its Consequences, W. Weibull. A Review of Cumulative Damage in Fatigue, N. M. Newmark. Significance of Transition Temperature in Fatigue, C. W. MacGregor. The Influence of Metallographic Structure on Fatigue, P. L. Teed. Fatigue at Elevated Temperatures, N. J. Grant. The Techniques of Physical Metallurgy for Studying Fatigue Damage, J. T. Norton.

PRODUCTION

Extrusion of Plastics, Rubber, and Metals. Herbert R. Simonds, Archie J. Weith, and William Schack. New York, Reinhold Publishing Corporation, 1952. 454 pp., illus., diagrs., figs. $10.

The first part of the book, comprising about two-thirds of the material, is devoted exclusively to the extrusion of plastics. The versatility of the extruding machine as an industrial unit is described, and the many applications of extruded plastics are discussed. Commercially important methods of dry extrusion, such as multiple-screw machines, multicolored products, sheets, and films and methods of compressing, pelletizing, and extrusion packaging are described in a detailed manner. The reminder of the book is concerned with the extrusion of metals—sheet, rods, and billet—and such materials as rubber, ceramics, and graphite. The Appendix contains a glossary, lists of manufacturers of extruded products and extrusion equipment, and tables and conversion factors.

REFERENCE WORKS

Handy Technical Dictionary in 8 Languages, Illustrated. London, K. L. R. Publishers Limited, 1952. 1088 pp., illus. £6 6s.

The subject coverage of this dictionary includes aviation, chemical and electrical equipment, hardware, machine tools, metalworking machinery, measuring and testing instruments, motors, radio and television, shipping, tools, welding equipment, and woodworking machinery. Terms are given in English, German, Polish, Russian, French, Italian, Portuguese, and Spanish. The volume is divided into three parts. The first contains a number of technical terms and phrases arranged in major divisions of engineering. Explanation of these terms is done by means of illustrations. The second part is a vocabulary that covers primarily a basic list of terms not included in the first part. Then indexes in eight languages are given, subdivided into two sections: the first, an alphabetical list of the terms; the second, a classified list of the illustrations. Notes on pronunciation are given in the introductory pages. Literature references are provided in footnotes; the book concludes with a 12-page bibliography of polyglot technical dictionaries, English technical dictionaries and encyclopedias, bilingual technical dictionaries, foreign technical dictionaries, and English and foreign dictionaries and enclyclopedias.

Brief Subject and Author Index of Papers in the Proceedings, 1937-1951. London, The Institution of Mechanical Engineers, 1952. 108 pp.

For information on I.A.S. Library Service Facilities, see page 91

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

SCIENCES, GENERAL

MATHEMATICS

The Design and Analysis of Experiments. Oscar Kempthorne. New York, John Wiley & Sons, Inc., 1952. 631 pp. $8.50.

The author wrote this book with three groups of users in mind: the experimenter, who needs to understand the theory and practice of the statistical designs; the consulting statistician, who wants a description of basic theory and methodology of designs; and the mathematical statistician, who is concerned with the validity of the application of statistical techniques to the analysis of data. The techniques are presented in such a way that they can be understood by those with little mathematical training, but the mathematical justification is given for those who are interested. The range of validity of the statistical techniques is considered equally with the actual mechanism of the technique. Important topics covered are the analysis of multiple classification data, the whole procedure of randomization, randomization tests, the extensive treatment of factorial designs, fractional replication, incomplete block designs, and the validity of current methods of analysis of experiments. Mr. Kempthorne is Professor of Statistics, Iowa State College.

An Introduction to the Theory of Differential Equations. Walter Leighton. New York, McGraw-Hill Book Company, Inc., 1952. 174 pp., figs. $3.50.

This textbook presents a rigorous coverage of material necessary for a first course in differential equations with emphasis on the underlying theory. The fundamental existence theorem is used repeatedly to provide a basis upon which a systematic and rigorous theory can be built. The more useful formal methods of solving differential equations are covered, as well as applications. Most of the latter have been chosen in the area of classical mechanics. The volume contains a full treatment in the real domain of second-order linear differential equations having a regular singular point. The chapter on oscillation theory provides original material based on the author's research. Numerous exercises for student solution, solved examples, and answers to almost all problems are included. Dr. Leighton is Professor of Mathematics, Washington University.

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Bessel Functions; Part II, Functions of Positive Integer Order. Prepared on Behalf of the Committee for the Calculation of Mathematical Tables by W. G. Bickley, L. J. Comrie, D. H. Sadler, J. C. P. Miller, and A. J. Thompson. (British Association for the Advancement of Science, Mathematical Tables, Vol. 10.) Cambridge, England, At the University Press; New York, Cambridge University Press, 1952. 255 pp. $11.

This volume continues the tables given in Vol. 6 of the series to functions of positive integer orders up to twenty, for values of the argument up to 25 for the J and Y functions or to 20 for the I and K functions. The preliminary parts of the book include, in addition to a description of the tables, a short account of the methods used in calculating and checking them. In a section entitled Functions and Formulae, a list of formulas relevant to the functions tabulated in this volume is given. A section on interpolation, showing how values of the functions for arguments between those tabulated may be calculated, is included. For the 8-figure tables, standard methods, using the second differences therein printed, are recommended. Other methods, not depending on differences and which may be used with the 10-figure tables, are also described.

Charting Statistics. Mary Eleanor Spear. New York, McGraw-Hill Book Company, Inc., 1952. 253 pp., figs. $4.50.

This is a book on practical graphic presentation of statistical data, depicting not only types of charts and their appropriate use but also subject matter of economic interest. The fact is stressed that there are particular types of charts to show certain data to advantage, and that certain data are better left in tabular form. The illustrations at the beginning of each chapter and on the end papers give different graphic interpretations and analyses based on the same table. The author is a Visual Information Specialist with the Bureau of Labor Statistics of the U.S. Department of Labor.

Contents: Graphic Presentation. Planning the Chart. Line Charts. The Surface Chart. Column Charts. The Bar Chart. The Map Chart. Other Types and Their Use. Exhibits. Duplicating, Color, Television. Index.

SPACE TRAVEL

Across the Space Frontier. Edited by Cornelius Ryan. New York, The Viking Press, 1952. 147 pp., illus. $3.95.

This book is a considerably expanded version of a series of scientific articles which appeared in *Collier's* under the title "Man Will Conquer Space Soon." It is illustrated by Chesley Bonestell, Fred Freeman, and Rolf Klep. The first chapter, This Side of Infinity, by Joseph Kaplan, treats of the nature and composition of the earth's atmosphere, particularly at high altitudes. Prelude to Space Travel, by Wernher von Braun, covers the design and operation of rocket motors, rocket vehicles, and the space station, as well as the problems of take-off, trajectories, and landing. Heinz Haber discusses medical problems in Can We Survive in Space, and Willy Ley describes A Station in Space. Who Owns the Universe, by Oscar Schachter, is a consideration of the legal implications of space stations and space travel. Fred L. Whipple's The Heavens Open presents his views on travel to other parts of the solar system and the universe.

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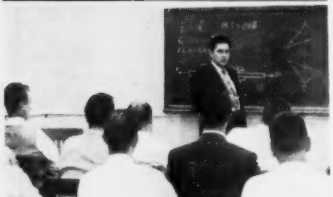

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444. Landing Gear Engineer—3 to 5 years of design and stress analysis experience. Knowledge of landing-gear drop testing also helpful. Must be capable of preparing stress reports. Salary commensurate with experience.

443. Aircraft Hydraulic Engineers—Knowledge of Aircraft Hydraulics essential. Acquaintance with military design specifications also helpful. Must have working knowledge of manufacturing and test procedures. Salary commensurate with experience.

438. Associate Professor or Professor—University in Midwest has opening for Ph.D. with interest in Aircraft Propulsion to teach undergraduate Aeronautical and Mechanical Engineering courses and to conduct sponsored research. Extensive laboratory facilities available. Title and salary commensurate with qualifications.

436. Engineer-Accountant—Expanding Westchester aeronautical firm has staff position open as Assistant to the President for young man with both theoretical engineering and accounting background. From 2–5 years' industrial experience is desired.

Available

449. Engineer—B.S. in M.E., M.E. Offering an outstanding record in design development, sales engineering, and administrative experience for last 13 years. Extensive experience in aircraft structures, light-alloy products design, and reinforced plastics production and design form technical background. Author of several papers on these subjects. Proved capability of group direction. A wide range of interests aids facility of meeting people easily. Seeking supervisory or administrative position in industry allied with above subjects. Will consider sales engineering territory for large basic material producing company. Complete résumé upon request. Please indicate nature and salary range of available positions in first letter.

448. Washington Representation—Well-established and competent technical representative desires part-time representation work before Government agencies for one or two additional clients on retainer fee basis. No commission work accepted.

446. Translator—Russian translator interested in part-time work on technical and scientific subject matter in the aeronautical engineering field. Postgraduate engineering degree and 15 years' experience in various phases of air-frame, engine, and equipment manufacture and test. Familiar with current developments and terminology in aircraft and guided missiles.

442. Canadian Engineering Sales Executive—With Dominion-wide personal contacts in aviation and industrial fields; seeks contact with United States company interested in entering or improving organization in Canada. First-class references available. Presently, General Sales Manager for Canadian company. Will consider manufacturing or representation for mechanical components, all systems.

441. Engineer—B.S. Aero. Engr. Supervisory experience as assistant chief of laboratory. Experience in the following categories: dimensional inspection including use of vernier-type equipment, supermicrometers, profilometers, comparators, and other high-precision equipment; layout and stress analysis of structural jigs and fixtures; electrical testing including use of multimeters, oscillographs, strain gages, and other electrical equipment; testing for physical properties of metals, plastics, rubber, and cloth including use of various types of tension, compression, and fatigue machines; testing and analysis of corrosion-resistance properties of metals; microexamination of metal structures including use of metallograph, polishing, etching, and molding machines; operation and analysis of magnetic particle testing and static process of inspecting nonmetallic materials; operation of X-ray machine and analysis of radiographs of metal components; photographic work including copying, developing, printing, and photomacrographs; correlated data from various departments and report writing; assisted in setting standards for classification of metal defects.

440. Aero-Mechanical Engineer—B.M.E., age 33. Eleven years' experience in the aircraft industry comprising guided missile electromechanical systems development, flight-test research, and stress analysis. Three most recent years in supervision as assistant project electromechanical engineer and project test engineer. Experience includes directing electrical system design, environmental test program, booster rocket installation design, test equipment design, flight-test programs. Familiar with military specifications. Seeking supervisory or administrative position in aircraft, missile, or allied field in New York City area only.

439. Representative or Government Contract Administrator—B.A. and M.B.A. degrees. Fourteen years' aviation experience: production specialist and buyer, Wright Field; assistant director—export sales, prominent aircraft manufacturer, etc. World War II test pilot and Air Force Factory Representative. Desires affiliation with aviation division of commercial equipment organization. Opportunity important. Current salary $7,000. Brochure upon request.

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